TECHNICAL PROGRESS REPORT #9

Type of Report: Quarterly

Reporting Period Start Date: January 1, 2006
Reporting Period End Date: March 31, 2006

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Date Report Issued: June 19, 2006

COOPERATIVE AGREEMENT: DE-FC26-04NT41768

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Disclaimer

Abstract

This report is the fifth quarterly Technical Progress Report submitted by NeuCo, Incorporated, under Award Identification Number, DE-FC26-04NT41768. This award is part of the Clean Coal Power Initiative ("CCPI"), the ten-year, $2B initiative to demonstrate new clean coal technologies in the field.

This report is one of the required reports listed in Attachment B Federal Assistance Reporting Checklist, part of the Cooperative Agreement. The report covers the award period January 1, 2006 – March 31, 2006 and NeuCo's efforts within design, development, and deployment of on-line optimization systems during that period.

Table of Contents

List of Graphical Materials

1 Introduction

The objective of the first CCPI Solicitation (DE-PS26-02NT41428) is to improve emissions, efficiency, maintainability and asset life of coal-based generation and bolster the long-term viability of the United States' abundant coal resources. The first round awards entail a $1.3 billion cost-shared partnership between the industry and government to demonstrate advanced coal-based power generation technologies that could help meet the President's Clear Skies and Climate Change initiatives.

NeuCo is one of eight companies selected as winners in this initial round. DOE awarded NeuCo a 4-year technology development initiative to design, develop, and demonstrate integrated on-line optimization systems at Dynegy Midwest Generation's Baldwin Energy Complex (BEC), which is the host site for the project. The total project budget is approximately $19 million.

NeuCo is shouldering 55% of the total project cost; while DOE is providing the remaining 45%. The DOE requires repayment of its investment. This repayment will result from commercial sales of the products NeuCo develops under the project. Dynegy Midwest Generation is contributing the host site, human resources, and engineering support to ensure the project's success.

2 Executive Summary

NeuCo has continued the design, definition, development, deployment, and data analysis efforts around the Optimizers (CombustionOpt, SCR-Opt, SootOpt, PerformanceOpt, and MaintenanceOpt) and the platform (ProcessLink).

2.1 Definition

During this reporting period, substantial effort has been put toward incorporating the feedback achieved from the real-time results as well as user interaction with the ProcessLink Optimizers. This includes graphical placement of certain new and/or refined functions, as well as the corresponding backend requirements, which facilitates multiple Optimizer communications.

We received advice on some of the assumptions used for the Achievable Specification for PerformanceOpt, which we implemented with the objective to ensure that the Achievable results represent targets that can actually be reached.

Work continued on expanding the general set of triggers and diagnostic rules in the MaintenanceOpt knowledgebase as well as the knowledgebase of equipment health triggers, root causes and diagnostic heuristics; we also started to explore how best to represent reliability (a.k.a. equipment health) rules.

2.2 Development

During this period, substantial effort has been put towards reporting, investigation, and solving bugs in the software. In parallel, NeuCo's Technology Development group has been working with enhancements of the ProcessLink platform so that it will support the next releases of each of the Optimizers (CombustionOpt, SCR-Opt, SootOpt, PerformanceOpt and MaintenanceOpt) and additional Optimizer functionality requested by the product development group at NeuCo as well as real time users.

2.3 Deployment

CombustionOpt on Unit 3 was installed and taken into closed-loop directed learning (DOE) during the reporting period; this marks the milestone and we now have CombustionOpt installed on all Units at Baldwin.

The real-time system at Baldwin continues to be a very good platform for testing software performance, having a full-scope model running continuously on plant data, providing us with a realistic test case for product enhancements. The concept of running both release V1 and V2 of the ProcessLink platform on Units 1 and 2 for purposes of testing and validation has proven successful and given us much insight. The significant challenge has been to combine the monetized and non-monetized objectives so that the closed-loop optimization transition between V1 and V2 was performed in a smoothly manner, and supported the home pages (GUIs).

SootOpt continues to run in closed-loop at Baldwin Unit 3, OMU Units 1 and 2. The work at OMU to extend the scope of SootOpt to non-ISB systems is proceeding on schedule.

PerformanceOpt on Unit 1 continues to run; we have been testing the convergence routines to improve the real-time success rate. The model for Unit 2 was built, QA'd, tested, deployed and ran on-line for the last weeks of the reporting period. We have experienced some convergence errors, and thus worked with to fine-tune the model convergence algorithms.

Tuning of the Optimizers (CombustionOpt, SCR-Opt, SootOpt, PerformanceOpt, and MaintenanceOpt) has been done throughout the period; we have had discussions with real-time users and gained valuable feedback especially from the Operations and Management staff at Baldwin.

2.4 Data Analysis

Data analysis for CombustionOpt, SCR-Opt, SootOpt, PerformanceOpt, and MaintenanceOpt was ongoing during the period; several refinements were made to the models based upon insights learned from the real-time results.

We have focused on the O2 controller and the measured O2 values for CombustionOpt, as well as the NH3 flow for SCR-Opt. The analysis of SootOpt has given us an increased understanding about the relationships between soot cleaning actions and their effects on various boiler parameters, as well as a better understanding of timing relationships between soot cleaning control actions and their effects.

We are continuing to add trigger variables to our knowledge data base for PerformanceOpt based on the experience gained at Baldwin, as well as adding the corresponding cost impact to MaintenanceOpt to be able to accurately populate the diagnostic service.

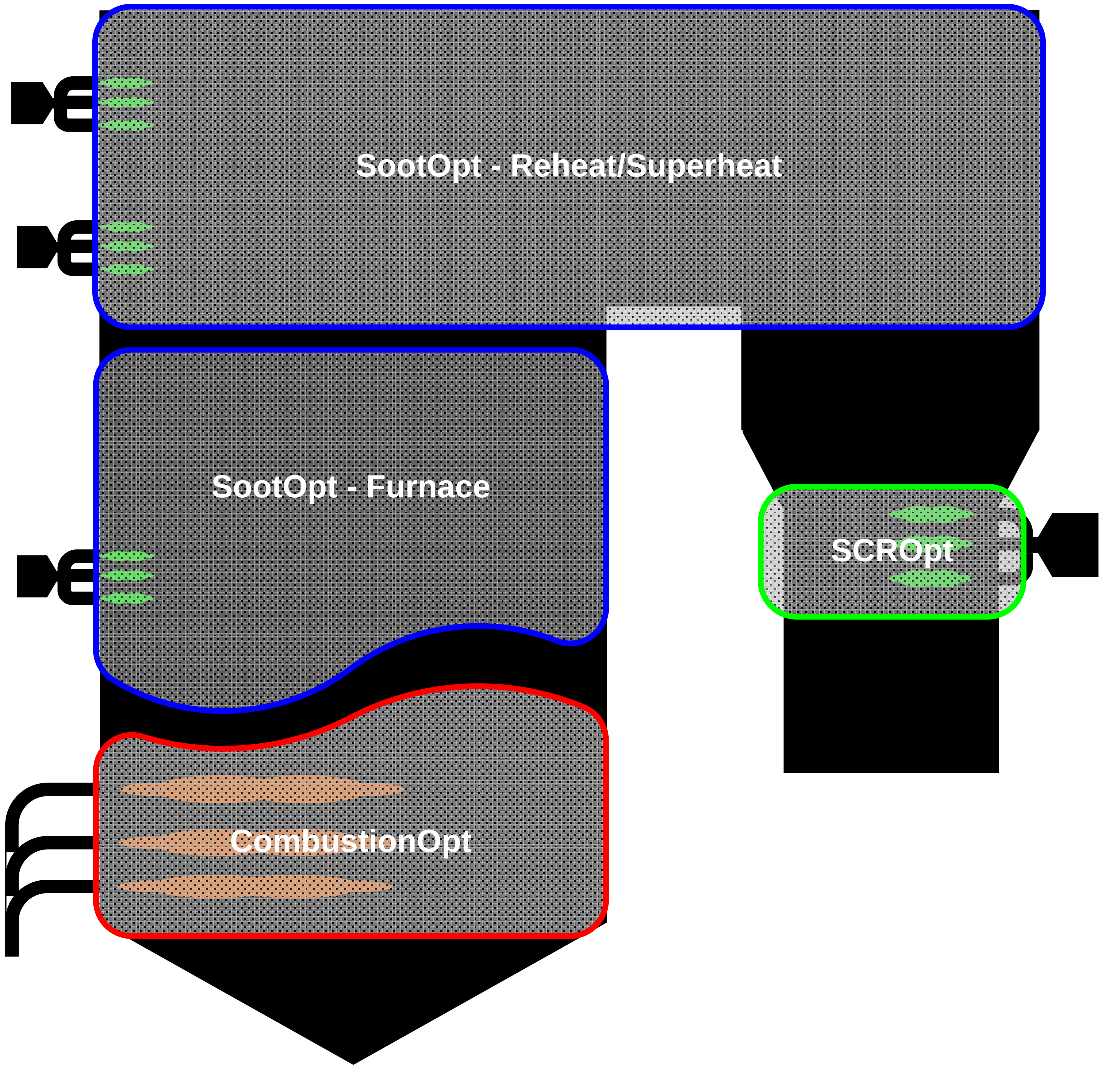

Figure 1 Overview of the neural Optimizers at Baldwin

3.1 Overview

From January 1 through March 31, 2006, the Technology Development and Product Management groups at NeuCo continued the design, use case analysis, technology review and architectural analysis of CombustionOpt for cyclone boilers and of the SootOpt, SCR-Opt, PerformanceOpt, and MaintenanceOpt products. During this period, the Application Engineering group at NeuCo has had a special focus on the transition from the old version of the platform to the new release (V2) and the associated import, QA, and data validation between the two releases. They also continued the on-site modifications to CombustionOpt, SCR-Opt, SootOpt, PerformanceOpt, and MaintenanceOpt parameters. The Product Management and Application Engineering groups at NeuCo performed data analysis of CombustionOpt, SCR-Opt, SootOpt, PerformanceOpt, and MaintenanceOpt operational data.

Development of the next release of the products continued according to plan and is provided in the relevant sections below.

A major effort during this period has been to further improve the stability and reliability of the software in real-time operation, as well as in depth testing, QA, and bug-fixing of the most recent release of the ProcessLink platform at Baldwin.

2.5 CombustionOpt

2.5.1 Definition

2.5.1.1 Goals for the Past Quarter

- Continue the design and definition around the next release of CombustionOpt based on the results achieved in real-time operation as well as continue improving the design and work flow around the GUI (Homepage)
- Continue to clarify issues specific to Cyclone boilers
- Aid with PI Maintenance

2.5.1.2 Accomplishments

Design and Definition

Work to refine the new closed-loop Optimizer and integrate the updated modeling and optimization strategy into the benchmarking and other advanced features of the Home Page has continued, with the focus on performance issues, data analysis, and verification. This includes graphical modifications of certain new and/or refined functions, as well as the corresponding backend requirements.

The backend definition work relates to the interaction of multiple Optimizers and involves multiple iterations between observed requirements at Baldwin as well as other sites and technical specifications defined by NeuCo's Software Development group.

Issues specific to Cyclone boilers

Optimization objectives have been changed to focus on the O2 controller and the measured O2 value, as well as NH3 flow, in response to a discussion held with Baldwin management and Operations in late December of 2005.

PI

Baldwin has completed a split of their PI System; previously they had one PI-server for all three units. Each one of the units now has a dedicated PI server.

2.5.2 Development

2.5.2.1 Goals for the Past Quarter

- Identify and fix bugs in CombustionOpt V2.0 and port to the next release
- Continue to empower and extend ProcessLink so that it supports new CombustionOpt functionality.
- Continue to develop functionality that supports multiple Optimizer interoperability

2.5.2.2 Accomplishments

Software Enhancements

The work with reporting, investigation and solving bugs as well as testing and QA of the most recent CombustionOpt release has been on-going during the reporting period.

In parallel, NeuCo's Technology Development group is working on further enhancements to the ProcessLink platform and the development is moving forward in a progressive manner. The next major release of the software is planned to Q206.

2.6 SCR-Opt

2.6.1.1 Definition

2.6.1.2 Goals for the Past Quarter

- Continue the design and definition around the next release of SCR-Opt based on the results achieved in real-time operation as well as continue improving the design and work flow around the GUI (Homepage)
- Aid with the re-alignment of the LasIR slip analyzers
- Continue deploying new models and constraints to manage NH3 flow

2.6.1.3 Accomplishments

Design and Definition

Work to refine the most recent release of the closed-loop Optimizer continued during the reporting period. This includes graphical placement of certain new and/or refined functions, as well as the corresponding backend requirements.

The backend definition work relates to the interaction of multiple Optimizers and involves multiple iterations between observed requirements at Baldwin and other sites and technical specifications defined by NeuCo's Software Development group.

LasIR

The LasIR slip analyzers were re-aligned and checked out during the reporting period.

New models

NeuCo has continued the work with tuning of the models of NH3 flow and other manipulated variables (MV's) impacting the SCR-Opt models.

2.6.1.4 Goals for the Past Quarter

- Identify and fix bugs in SCR-Opt V2.0 and port to the next release
- Continue to empower and extend ProcessLink so that it supports new SCR-Opt functionality.
- Continue to develop functionality that supports multiple Optimizer interoperability

2.6.1.5 Accomplishments

Software Enhancements

The work with reporting, investigation and solving bugs as well as testing and QA of the most recent SCR-Opt release has been on-going during the reporting period.

In parallel, NeuCo's Technology Development group is working on further enhancements to the ProcessLink platform and the development is moving forward in a progressive manner. The next major release of the software is planned to Q206.

2.7 SootOpt

2.7.1 Definition

2.7.1.1 Goals for the Past Quarter

- Continue the design and definition around the next release of SootOpt based on the results achieved in real-time operation, as well as continue improving the design and work flow around the GUI (Homepage)
- Continue the efforts with soot cleaning vendors (ASI, ECS, Solvera) for interfacing with their different systems
- Continue the efforts with modeling and optimization

2.7.1.2 Accomplishments

Design and Definition

The definition efforts for the user interface, and the graphical modification of certain functions has been on-going during the period, and NeuCo continued to refine the user interface requirements definition.

The backend definition was focused on developing the next steps; both in terms of ASI's modules, as well as requirements for the interface with non-ISB systems and the work to extend the scope of SootOpt is proceeding on schedule.

ASI, ESC, and Solvera

NeuCo continued the discussions with ASI about possible enhancements to the interface between the ASI soot cleaning systems and SootOpt, especially regarding the following:

- Providing SootOpt with more information about when the ASI system is acting on the type of trigger we are biasing (i.e. the backstops). Max Time based triggering, in addition to the sintering detection algorithms, and the repeat cleaning behavior, make sorting this out of the data post trigger really challenging.
- Allowing SootOpt to recommend to the ASI system that the FCM activity be paused when the global considerations we model imply that a pause would be a good thing; and

- Allowing SootOpt to recommend to the ASI system that some sequence(s) in the backpass be run or paused/aborted in the situation where the SCE is not in operation.

A specification for an enhancement to the ASI interface addressing key pieces of information related to the activity of the FCM was developed by NeuCo and ASI. We also reached a general agreement on how to expand on the existing interface to the furnace module and improve on the convection pass integration with SootOpt on Unit 3.

NeuCo and Solvera collaborated to resolve the problem with intermittent bad quality data reported in the previous period, and the updated datalink software and hardware have been performing well during the reporting period and we have not seen the problem with bad quality data since the upgrade was done.

Modeling and Optimization

The evaluation of various neural modeling strategies, including modeling using cleanliness factors, parameters representing soot blowing frequency, as well as parameters representing combustion conditions, was progressing during the reporting period.

We have continued the work on calculations to support reporting of sootblowing activities during the period.

2.7.2 Development

2.7.2.1 Goals for the Past Quarter

- Identify and fix bugs in SootOpt V2.0 and port to the next release
- Continue to empower and extend ProcessLink so that it supports new SootOpt functionality.
- Continue to develop functionality that supports multiple Optimizer interoperability

2.7.2.2 Accomplishments

Software Enhancements

The work with reporting, investigation and solving bugs as well as testing and QA of the most recent SootOpt release has been on-going during the reporting period. To support various calculations and heuristics configuration ProcessLink software updates were developed and implemented.

In parallel, NeuCo's Technology Development group is working on further enhancements to the ProcessLink platform and the development is moving forward in a progressive manner; the next major release of the software is planned to early Q306.

2.8 PerformanceOpt

2.8.1 Definition

2.8.1.1 Goals for the Past Quarter

- Continue the design and definition around the next release of PerformanceOpt based on the results achieved in real-time operation as well as continue improving the design and work flow around the GUI (Homepage)
- Refine understanding of detailed functionality needed in ProcessLink to support PerformanceOpt
- Refine Achievable Specification

2.8.1.2 Accomplishments

Design and Definition

The work with the ProcessLink functionality that is needed to support the capabilities of PerformanceOpt has progressed during the reporting period; NeuCo has worked closely with Black and Veatch and Baldwin to further refine the requirements around the condition variable triggering mechanisms and we have added new trigger variables throughout the reporting period.

With PerformanceOpt in routine operation on Unit 1, NeuCo has asked Baldwin to provide NeuCo with feedback on the application. The first review included recommendations for additional trigger variables, such as condenser backpressure and flue gas O2 that was added to our current list of variables that PerformanceOpt monitors. By combining these with corresponding cost impacts, these will help clarify where there are opportunities for improvement and what it is costing the plant to continue operating without addressing these issues.

NeuCo also continued to refine the user interface and backend requirements definitions for the next release of PerformanceOpt, based on the above mentioned feed-back as well as real-time usage at other customer sites.

The backend definition work relates to the interaction of multiple Optimizers and is ongoing, involving multiple iterations between observed requirements at Baldwin and other sites, and technical specifications defined by NeuCo's Software Development group.

Achievable Specification
NeuCo received advice from Black and Veatch on some of the assumptions used for the Achievable Specification, and we adjusted the Achievable Specification to more closely represent the plant potential. We are now using a curve to represent the HP turbine efficiency target, with lower efficiency at lower loads; previously we were using a constant efficiency, which caused the diagnostics service to trigger each time the unit ran at low loads. The model results are now more indicative of actual turbine potential.

2.8.2 Development

2.8.2.1 Goals for the Past Quarter

- Identify and fix bugs in PerformanceOpt V2.0 and port to the next release
- Continue to empower and extend ProcessLink so that it supports new PerformanceOpt functionality.
- Continue to develop functionality that supports multiple Optimizer interoperability

2.8.2.2 Accomplishments

Software Enhancements
The work with reporting, investigation and solving bugs as well as testing and QA of the most recent PerformanceOpt release has been on-going during the reporting period.

In parallel, NeuCo's Technology Development group is working on further enhancements to the ProcessLink platform and the development is moving forward in a progressive manner; the next major release of the software is planned to late Q206.

2.9 MaintenanceOpt

2.9.1 Definition

2.9.1.1 Goals for the Past Quarter

- Continue the design and definition around the next release of MaintenanceOpt based on the results achieved in real-time operation
- Continue improving the specification of the MaintenanceOpt GUI (Homepage)
- Expand the knowledge base and refine understanding of knowledge base of conditions, root causes and heuristics for the diagnostics intelligence of MaintenanceOpt

2.9.1.2 Accomplishments

Design and Definition

NeuCo worked with plant operations personnel at Baldwin to capture their feedback on the accuracy of problem identification/analysis and further enhance the effectiveness of the heuristics for diagnosis capabilities, based on their feed-back and other real-time users NeuCo continued to refine the user interface and backend requirements definitions for the next release of MaintenanceOpt.

Knowledge base expansion

Work also continued on expanding the general set of triggers and diagnostic rules in the MaintenanceOpt knowledgebase as well as the knowledgebase of equipment health triggers, root causes and diagnostic heuristics; we added new triggers to identify suboptimal unit performance as well as the main steam to the boiler feed pump turbines as well as their cost impact to the MaintenanceOpt displays. Next steps involve prioritizing the set to deploy for maximizing coverage of the controllable losses that the BEC plant engineering personnel monitor currently.

NeuCo also started to explore how best to represent reliability (a.k.a. equipment health) rules for MaintenanceOpt during the reporting period.

2.9.2 Development

2.9.2.1 Goals for the Past Quarter

- Identify and fix bugs in MaintenanceOpt V2.0 and port to the next release
- Continue to empower and extend ProcessLink so that it supports new PerformanceOpt functionality.
- Continue to develop functionality that supports multiple Optimizer interoperability

2.9.2.2 Accomplishments

Software Enhancements

The work with reporting, investigation and solving bugs as well as testing and QA of the most recent MaintenanceOpt release has been on-going during the reporting period.

In parallel, NeuCo's Technology Development group is working on further enhancements to the ProcessLink platform and the development is moving forward in a progressive manner; the next major release of the software is planned to early Q306.

3 Results and Discussion

3.1 CombustionOpt Results

3.1.1 Deployment

3.1.1.1 Goals for the Past Quarter

- Continue deployment of CombustionOpt on Unit 3
- Continue the efforts around ProcessLink V2 migration
- Continue deploying new models and constraints to manage Cyclone stability and NOx as well as fine-tune the models

3.1.1.2 Accomplishments

Unit 3 installation
The deployment of CombustionOpt on Unit 3 progressed; PI tags were set up, control logic changes performed, followed by DCS loop testing and training of plant personnel. The unit was put into closed-loop directed learning (DOE) at the end of the reporting period.

ProcessLink migration and ongoing tuning
Both release V1 and V2 of our ProcessLink platform and CombustionOpt Optimizer is now running in closed loop under a new configuration on both Units 1 and 2.

On both units (1 and 2) the following changes have been fruitful (please see Chapter 3.1.2 and *Figure 2 - Figure 17* for more details):

- Adding information about the time history of the O2 Servo signal to the inputs of all models.
- Replacing the Main Flame Quality signals with the Lighter Flame Quality signals, which are less prone to dropping out due to blocked line of sight.
- Adding optimization objectives Max and Min respectively for O2 and the O2 Servo.
- Re-tuning tolerances to include the new objectives.
- Removing the direct optimization of cyclone stoichiometry in favor of demonstrating better management of the O2 and OFA system interactions; we are considering re-introducing cyclone stoichiometry.

We have been running both platforms in parallel for purposes of testing and validation during the reporting period.

3.1.2 Data Analysis

3.1.2.1 Goals for the Past Quarter

- Ongoing analysis of the results

3.1.2.2 Accomplishments

Ongoing analysis

Optimization objectives have been changed to focus on the O2 controller and the measured O2 values; this is in response to discussions held with Baldwin (Sam Krueger and Operations management staff) at the end of 2005. The tuning is on-going but initial results are interesting; please see *Figure 2-Figure 10* below for details.

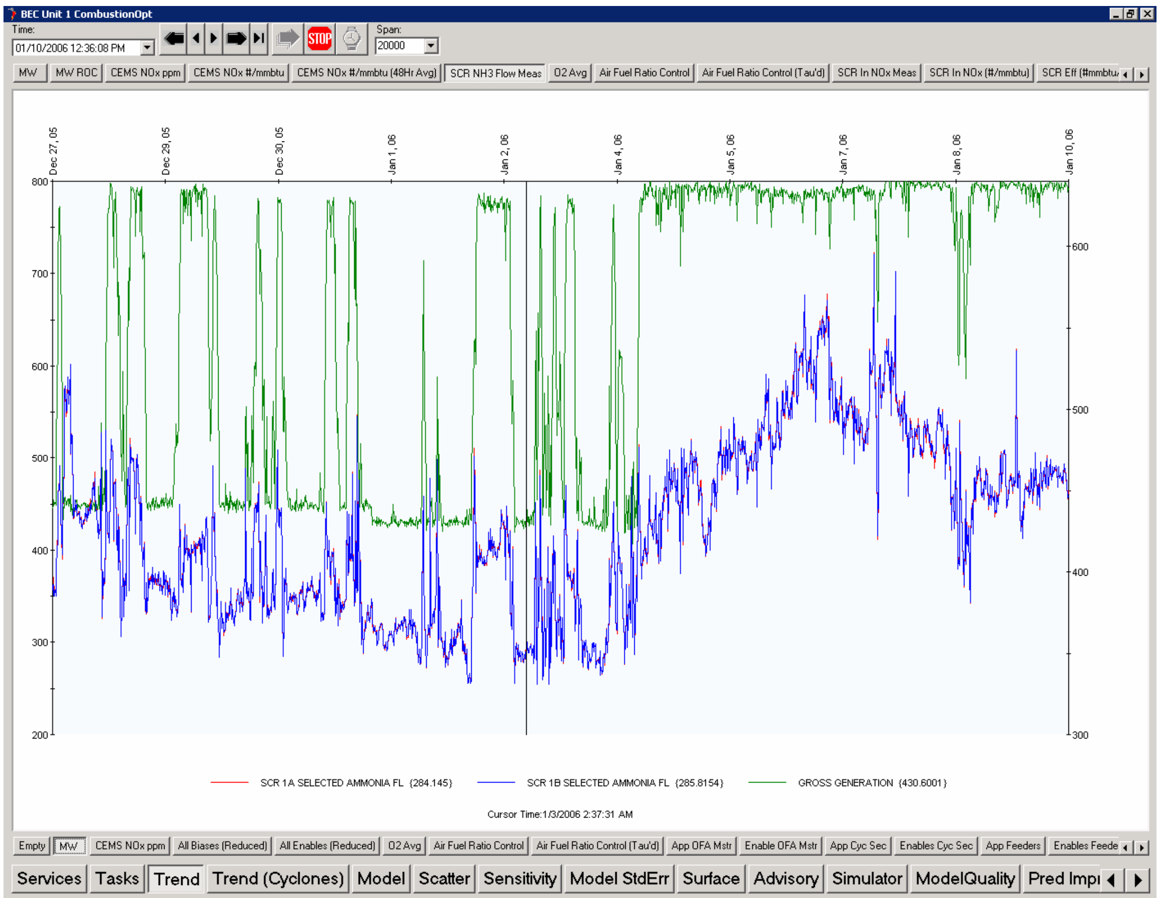

Figure 2 Unit 1 Combustion/SCR optimization study including O2 Servo (1 of 7)

Figure 2 shows MW (green line) along with SCR NH3 flow (blue line) for approximately two weeks. The unit has been cycling for purposes of coal conservation but went back to baseline operation around 1/5/06.

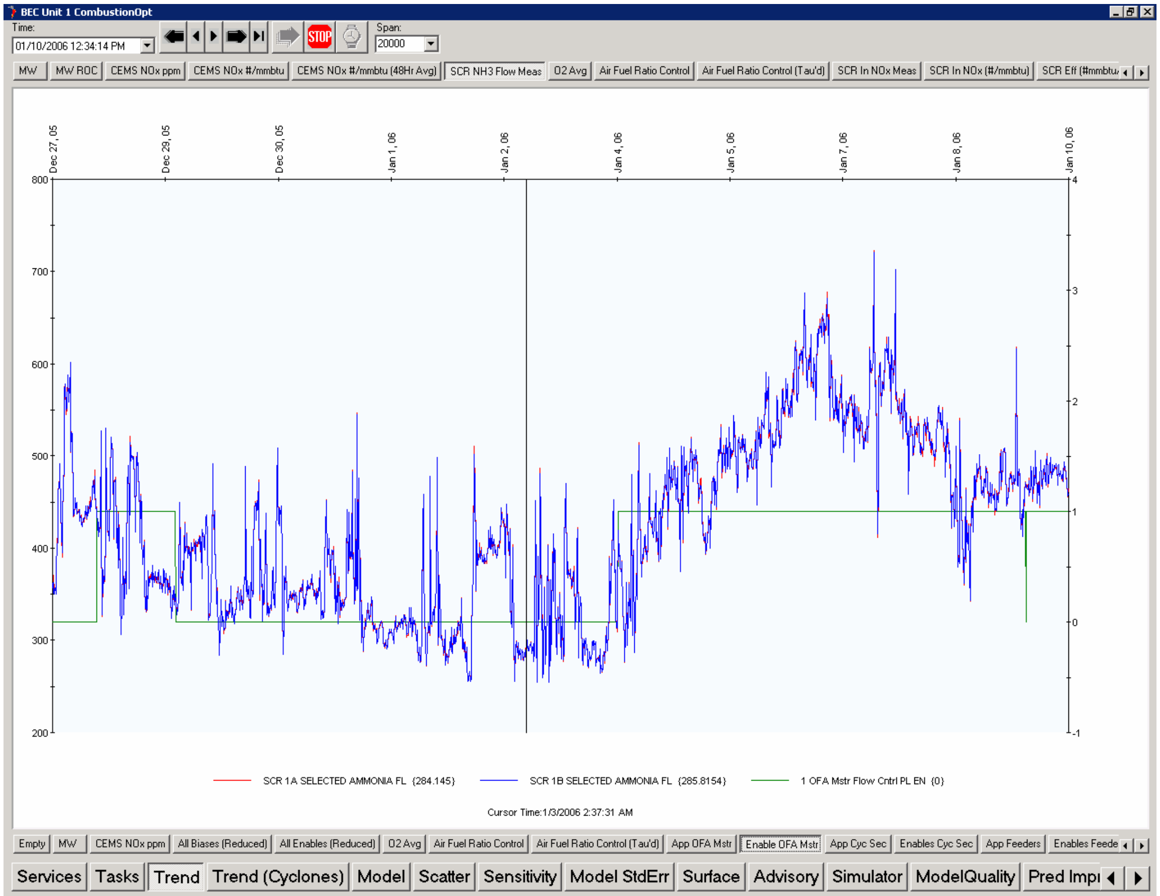

Figure 3 Unit 1 Combustion/SCR optimization study including O2 Servo (2 of 7)

Figure 3 shows NH3 flow (blue line) along with the OFA Master Bias Enable (green line). This enable represent the start of optimization explicitly focusing on the behavior of the O2 control system, along with NH3 flow.

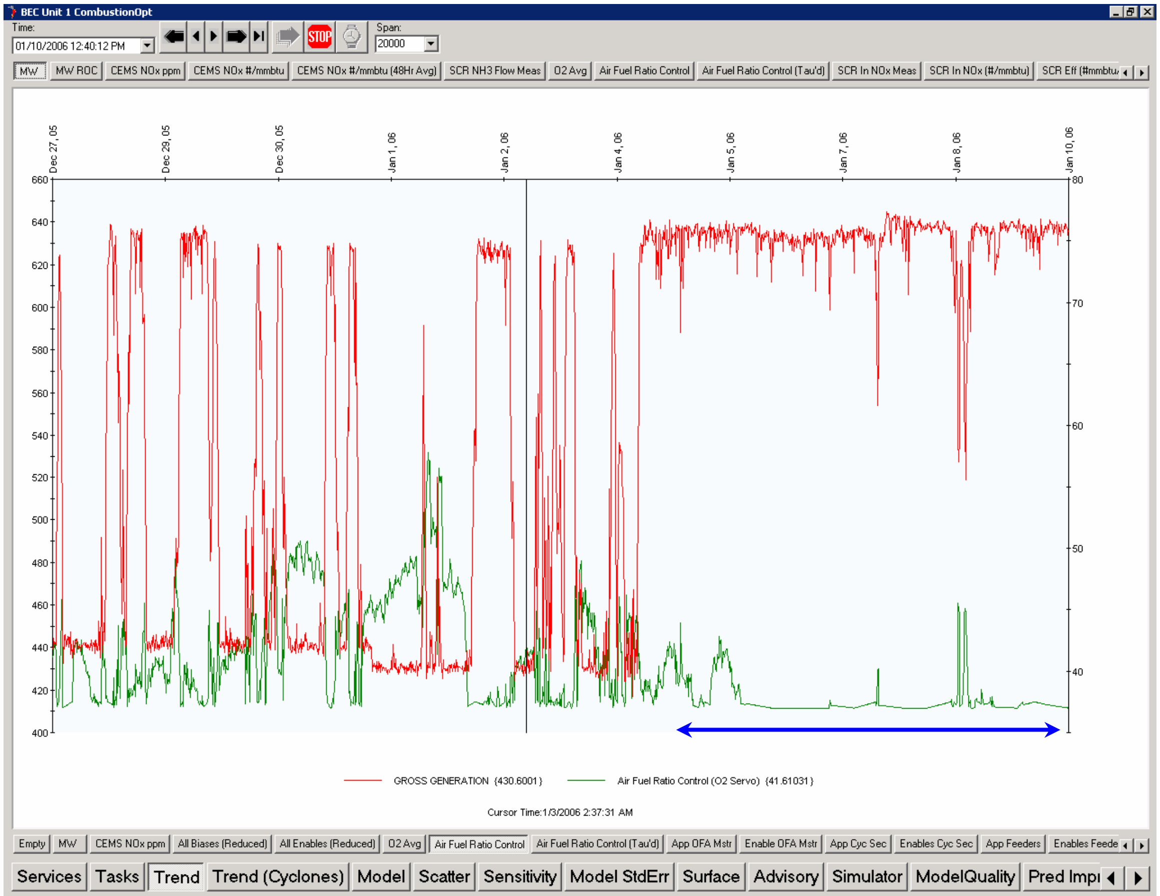

Figure 4 Unit 1 Combustion/SCR optimization study including O2 Servo (3 of 7)

This plot shows MW (red line) along with the O2 Controller (green line). Note that the O2 controller is backed down to around its low-limit of 37 (blue arrow) when Unit 1 is at full load; reasons for this are pretty mysterious, but definitely have to do with OFA flow and cyclone combustion characteristics. We will continue to investigate this during the coming months.

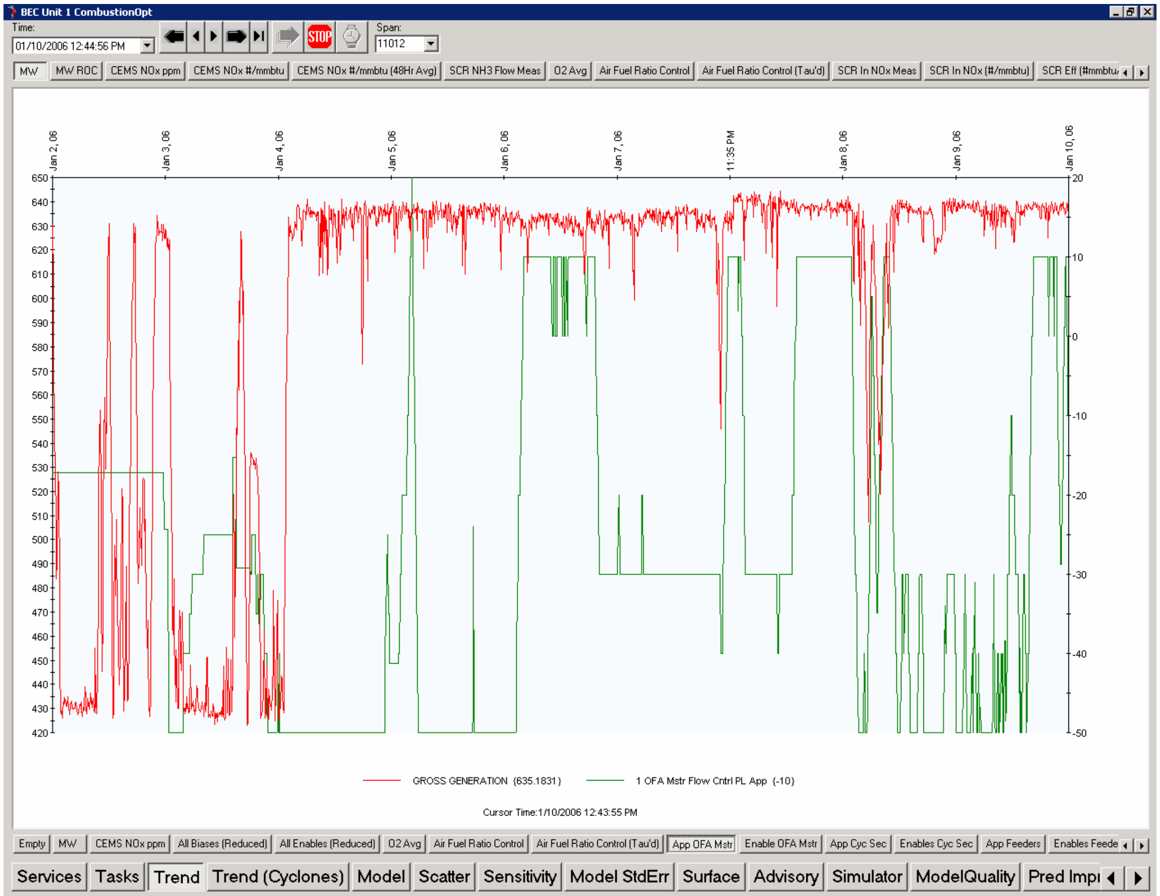

Figure 5 Unit 1 Combustion/SCR optimization study including O2 Servo (4 of 7)

This plot shows MW (red line) along with the OFA Master Bias (green line) for just the second week of the previous plot, as the optimization was tuned to work on keeping the NH3 flow down and also, where possible, keeping the O2 controller from bottoming out altogether and causing O2 to rise.

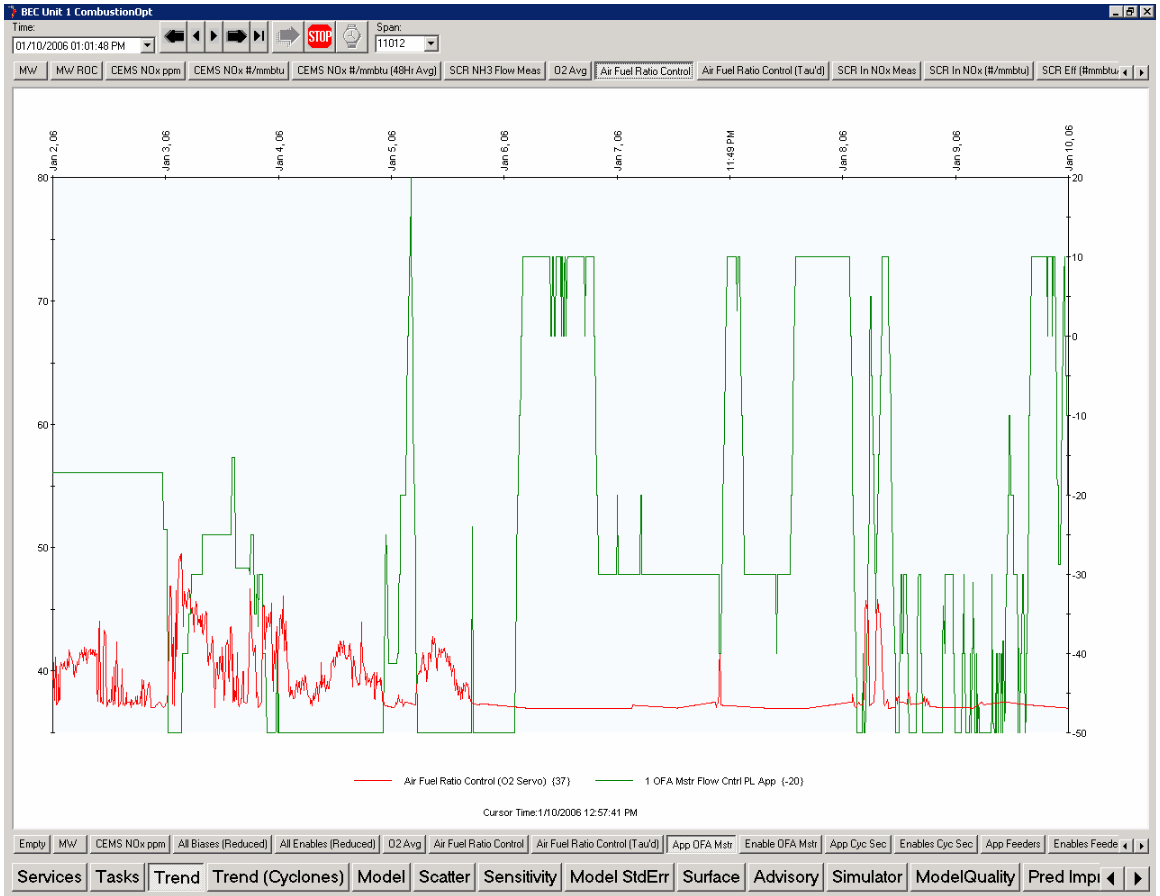

Figure 6 Unit 1 Combustion/SCR optimization study including O2 Servo (5 of 7)

Figure 6 shows only the OFA Master (green line) and the O2 Controller (red line) for the same time period as the previous plot (*Figure 7*).

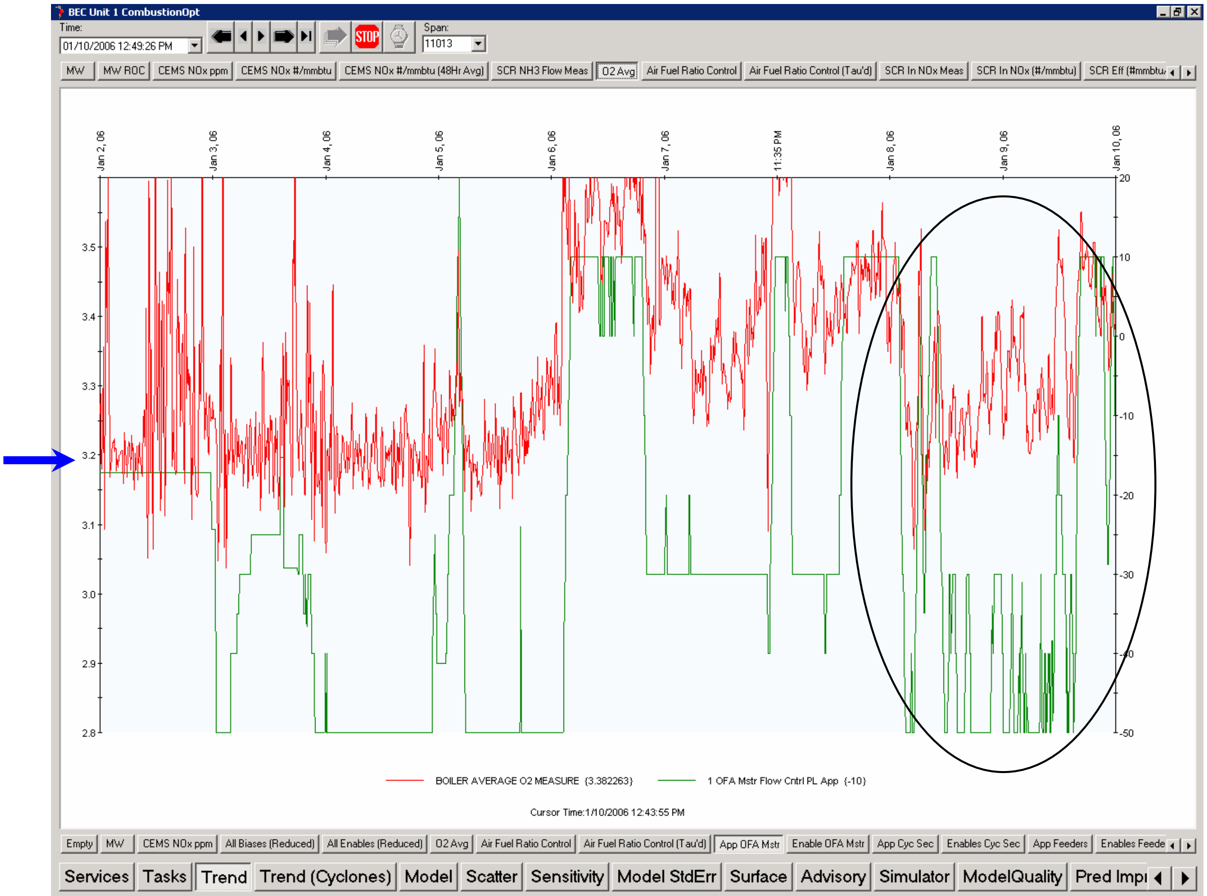

Figure 7 Unit 1 Combustion/SCR optimization study including O2 Servo (6 of 7)

This plot shows what happens to the measured O2 (red line) when the O2 controller bottoms out and the OFA master (green line) is biased up, namely the O2 controller cannot maintain O2 at its set point of 3.2%. In this kind of scenario, the O2 control loop is essentially stuck until either a load change happens, a dramatic change in coal quality occurs, or operator intervention decreases the excessO2 coming into the boiler.

The circled area shows how the Optimizer was responding to tuning efforts and on-line learning, by recognizing that closing down the OFA Bias brings the O2 measurement back into the ball-park.

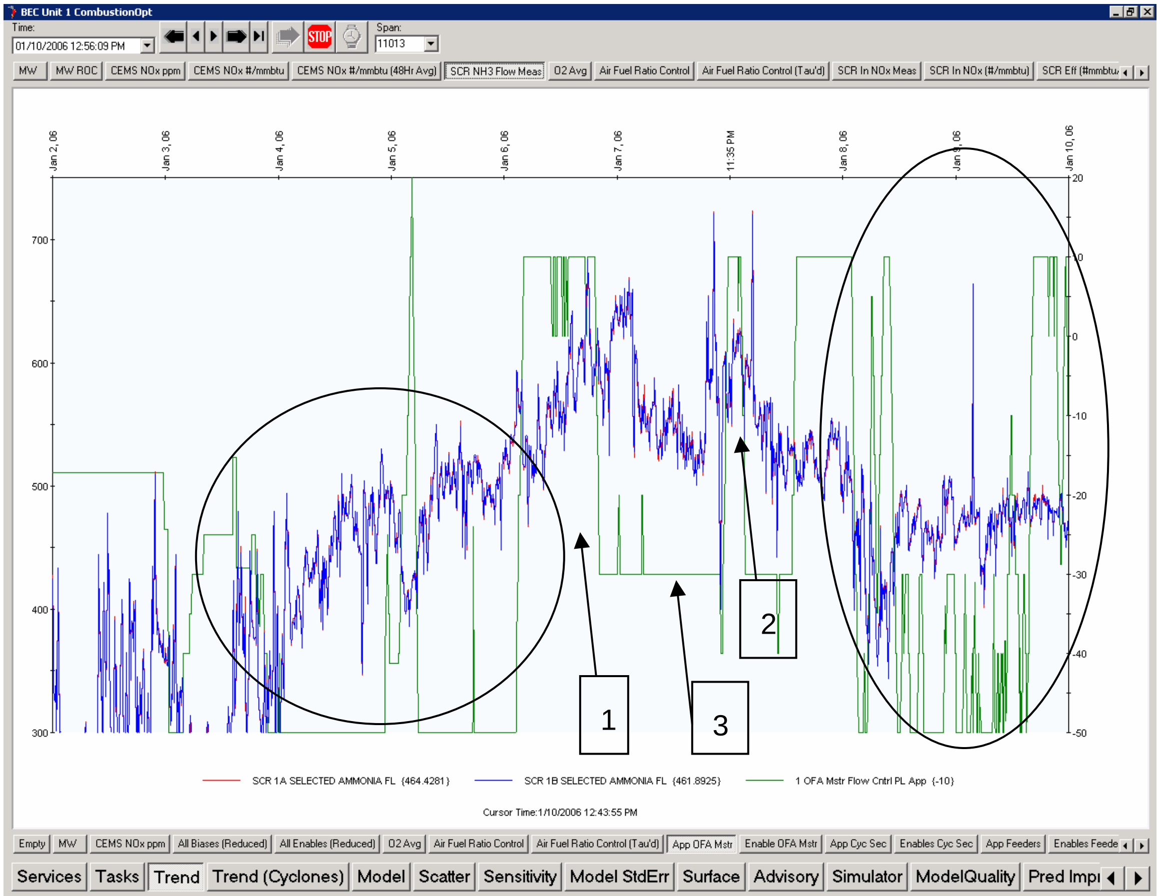

Figure 8 Unit 1 Combustion/SCR optimization study including O2 Servo (7 of 7)

This plot shows however, that the effect of OFA (green line) is not necessarily straightforward when it comes to NH3 flow (blue line).

- In the circled region to the left, during which the unit was settling in to base load operation, NH3 flow was increasing. Observing the previous screens, the O2 controller was barely off its low stop. This is not too surprising given the OFA Bias was pinched off.
- However, as arrows 1 and 2 show, increasing OFA is not always a good idea for controlling NOx (and NH3). In fact the suspicion is that when the cyclones operate with the O2 controller bottomed out (OFA high) the combustion deteriorates and they begin to produce tremendous NOx. Time spent outside the edges of the small stoichiometry and temperature window in which PRB slag is highly fluid may cause the dynamics in the cyclone to break down, leading to uneven temperature distribution, poor O2 efficiency, and eventually slag backing up.
- Arrow 3 suggests that just the right OFA flow is necessary when the cyclones are maxed out. The reversal of the OFA NOx/NH3 relationship as a function of O2 control, time, coal and mass-flow make this a tricky relationship to capture and optimize.

- The movement of the OFA master in the right circle suggests the Optimizer is beginning to get a handle on the balance.

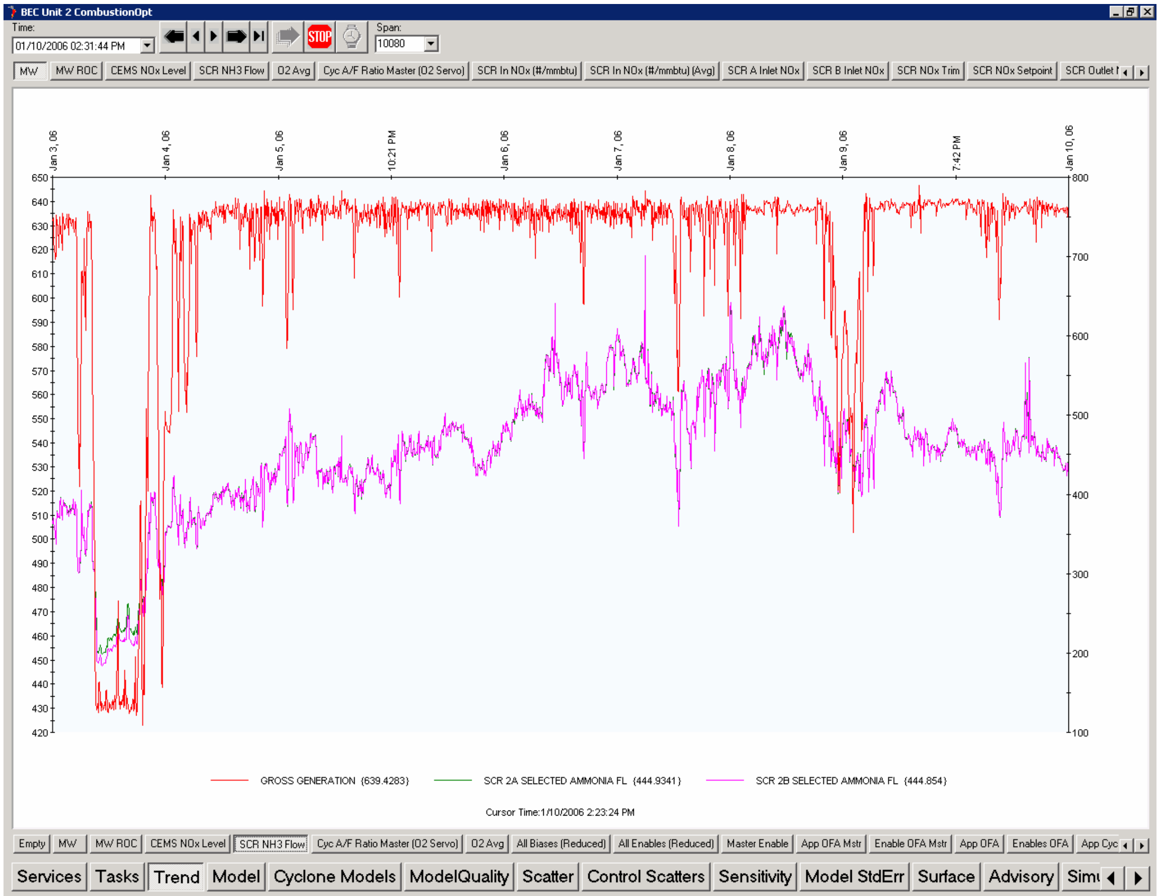

Figure 9 Unit 2 Combustion/SCR optimization study including O2 Servo (1 of 2)

This plot shows MW (red line) along with NH3 flow (magenta line) for Unit 2 for week ending 1/10. Unit 2 also went from cycling to base-load operation.

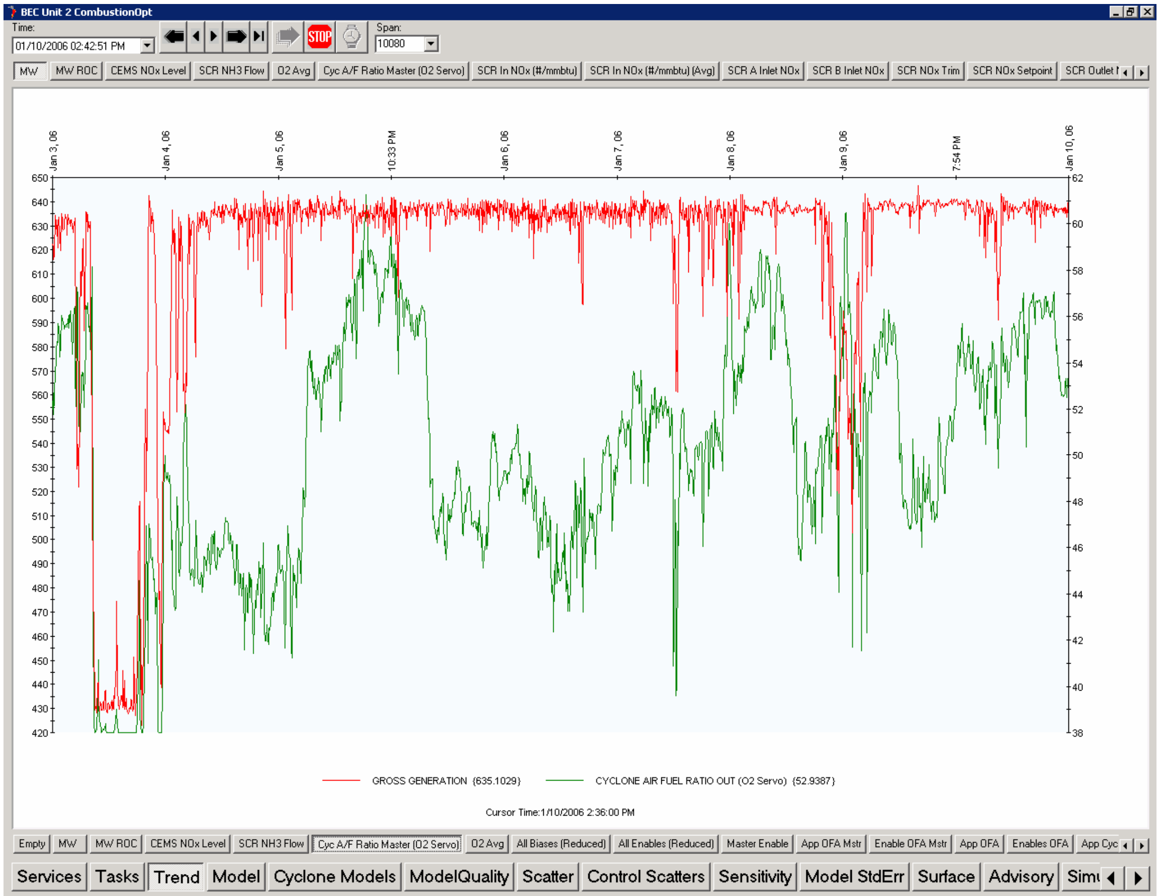

Figure 10 Unit 2 Combustion/SCR optimization study including O2 Servo (2 of 2)

This plot shows MW (red line) along with the O2 controller (green line). In contrast to Unit 1 the controller bottoms out at low load!? The reason for such different behavior between the two units is something BEC operations staff would like to understand better and those problems that we are constantly trying to investigate and analyze.

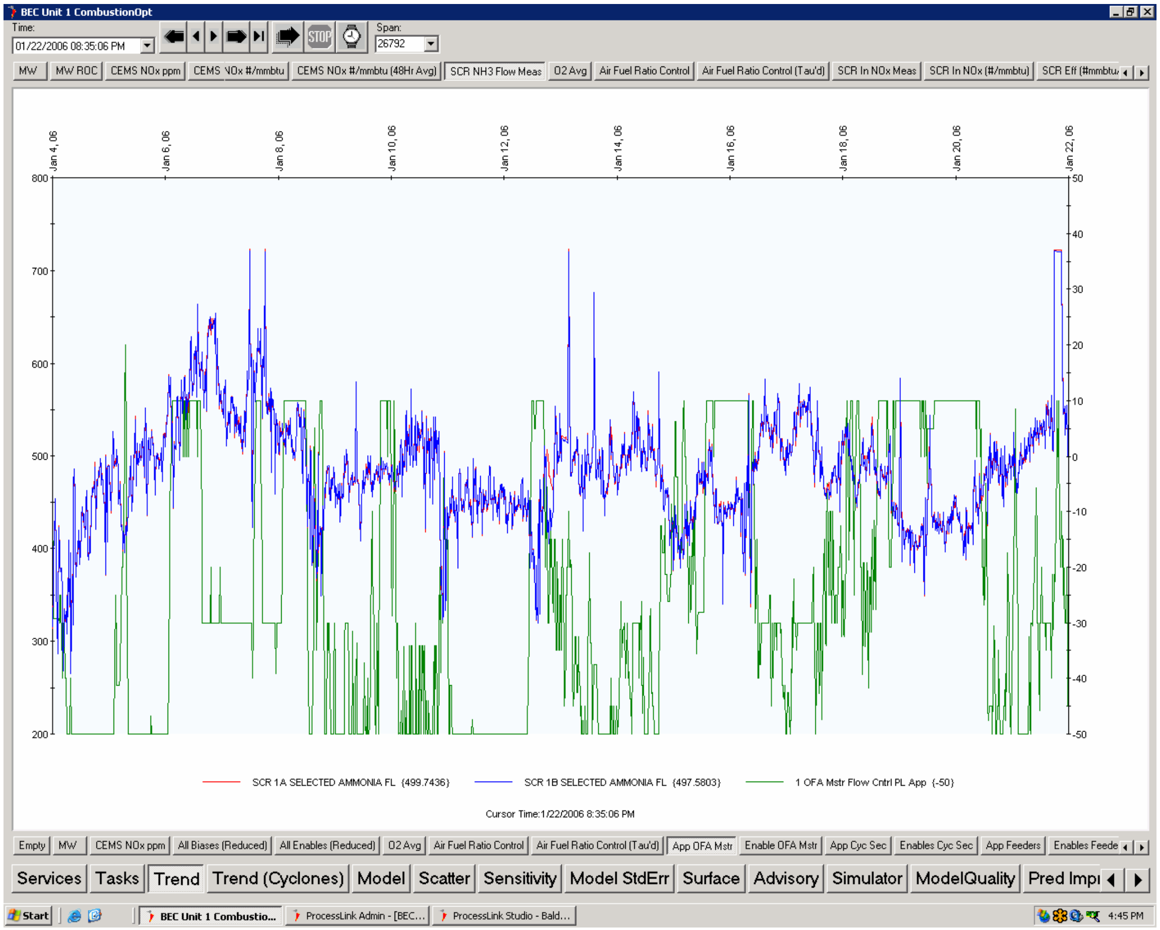

Figure 11 Unit 2 OFA Master modulating to control NH3 flow

Figure 11 shows the OFA master (green line) modulating to control NH3 flow (blue and red lines). This behavior represents an improved understanding of the nuances of the O2 and OFA system interacting. It is worth noting in the plot above, that sometimes to reduce NH3 flow, the OFA should be biased more closed, which goes counter to intuition but matches the reality of cyclone dynamics.

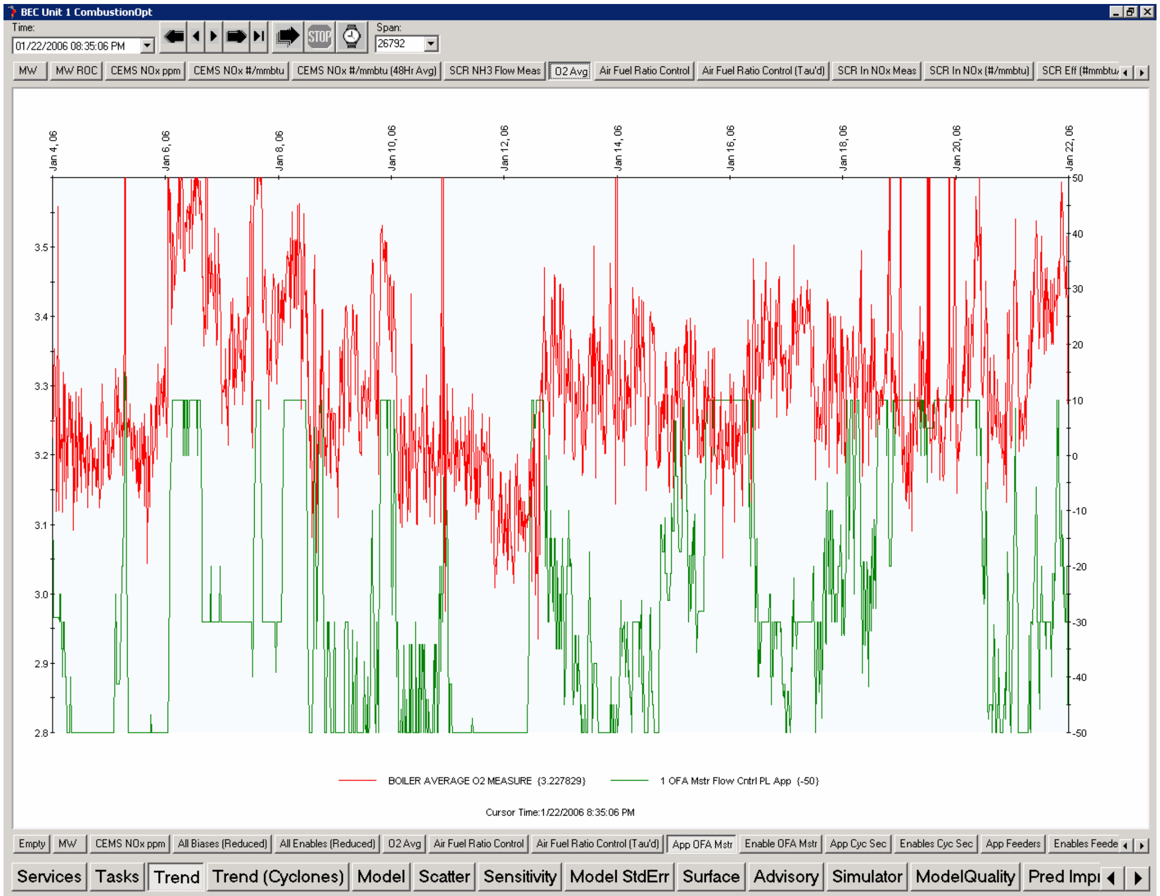

Figure 12 Unit 2 OFA Master and measured O2

This plot shows the measured O2 (red line). Again the use of the OFA master (green line) here indicates that CombustionOpt now knows that when NH3 flow is on the rise, and O2 is as well, then the OFA influence on NOx become inverted. The right thing to do in such cases is close it down, to re-stabilize cyclone combustion.

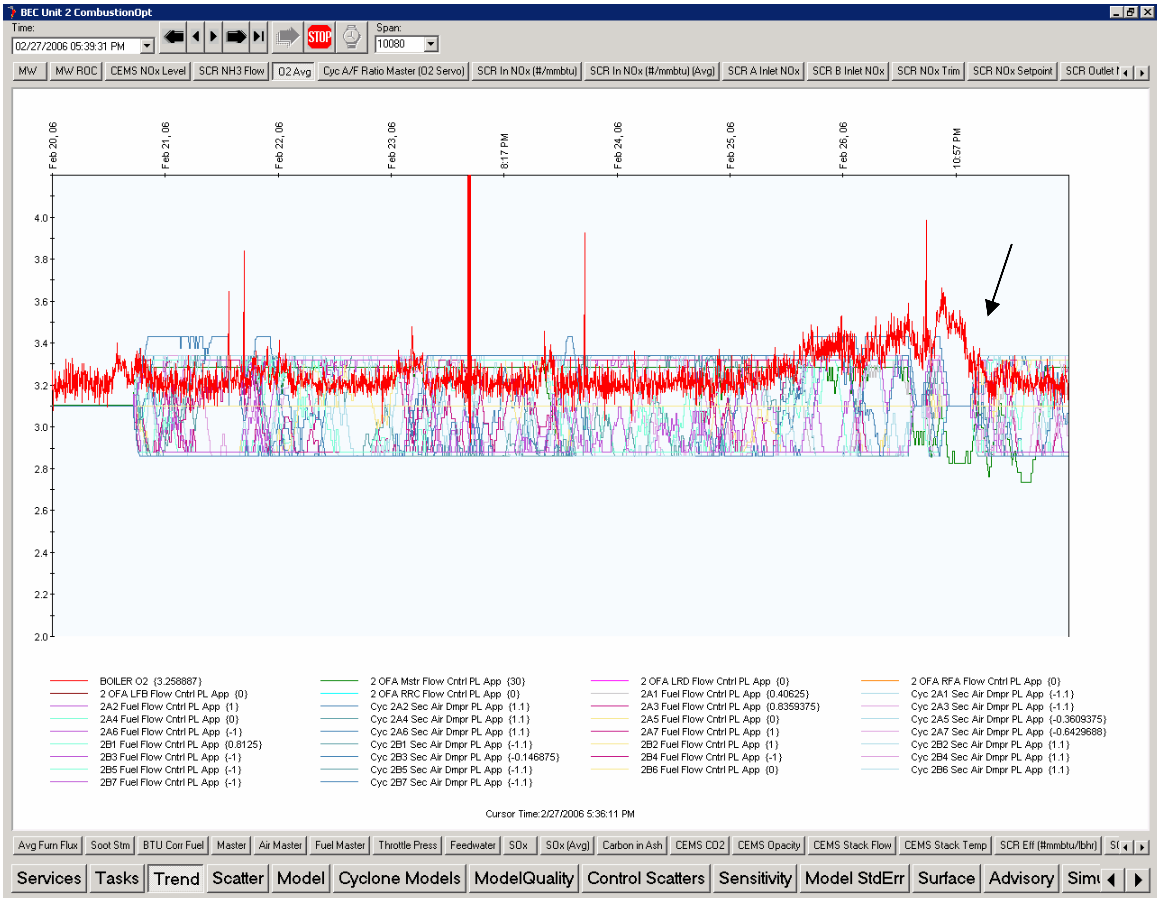

Figure 13 Boiler Outlet Average O2

Figure 13 shows the boiler outlet O2 average (red line) along with the applied biases (squiggly lines) under the control of CombustionOpt. The arrow shows an instance where the Optimizer responded to evolving poor performance by returning to a known setup. As can be seen, this expert rule is often a sufficient ‘reset’ to the process, and the Optimizer is soon able to get back to active biasing, with good results.

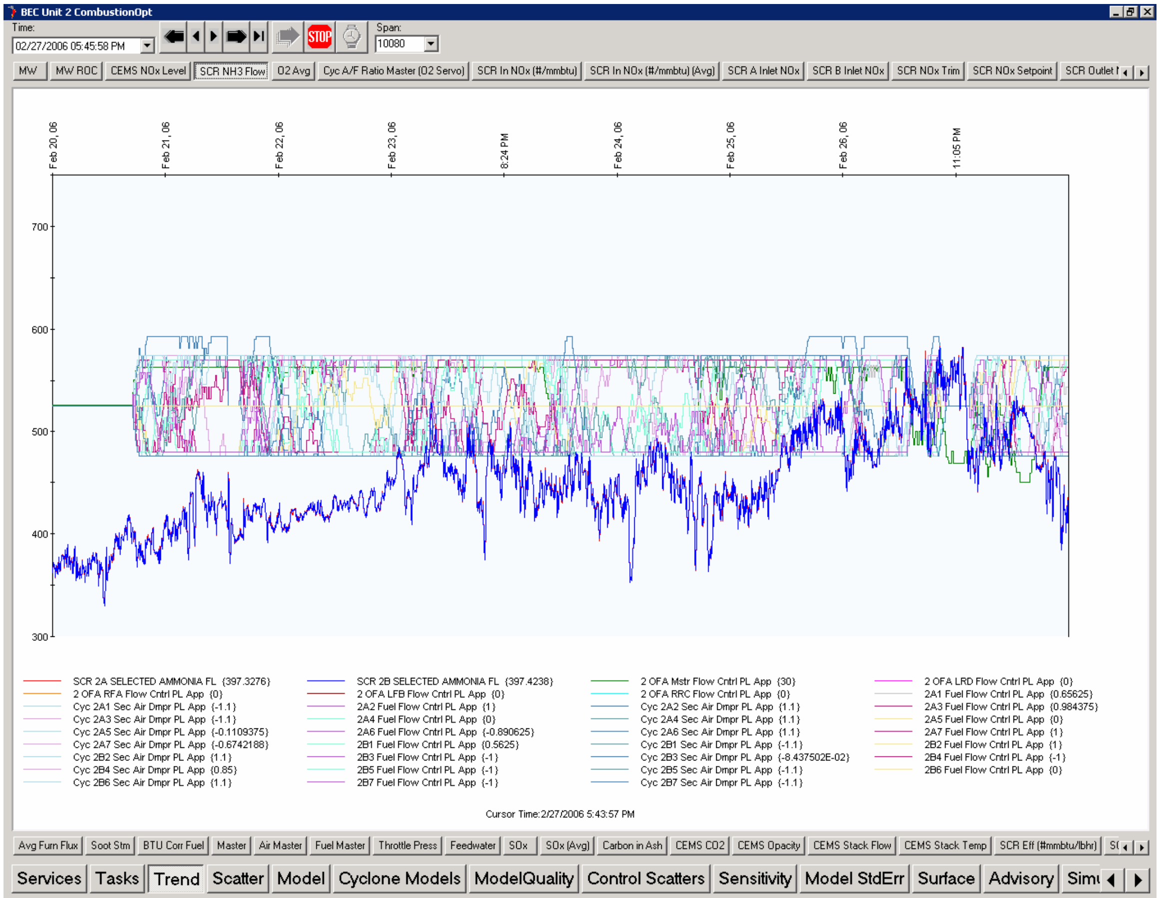

Figure 14 NH3 flow

Figure 14 shows NH3 flow over the same period. Both Unit 1 and Unit 2 began to experience degraded performance around the 2/25, most likely related to changing fuel.

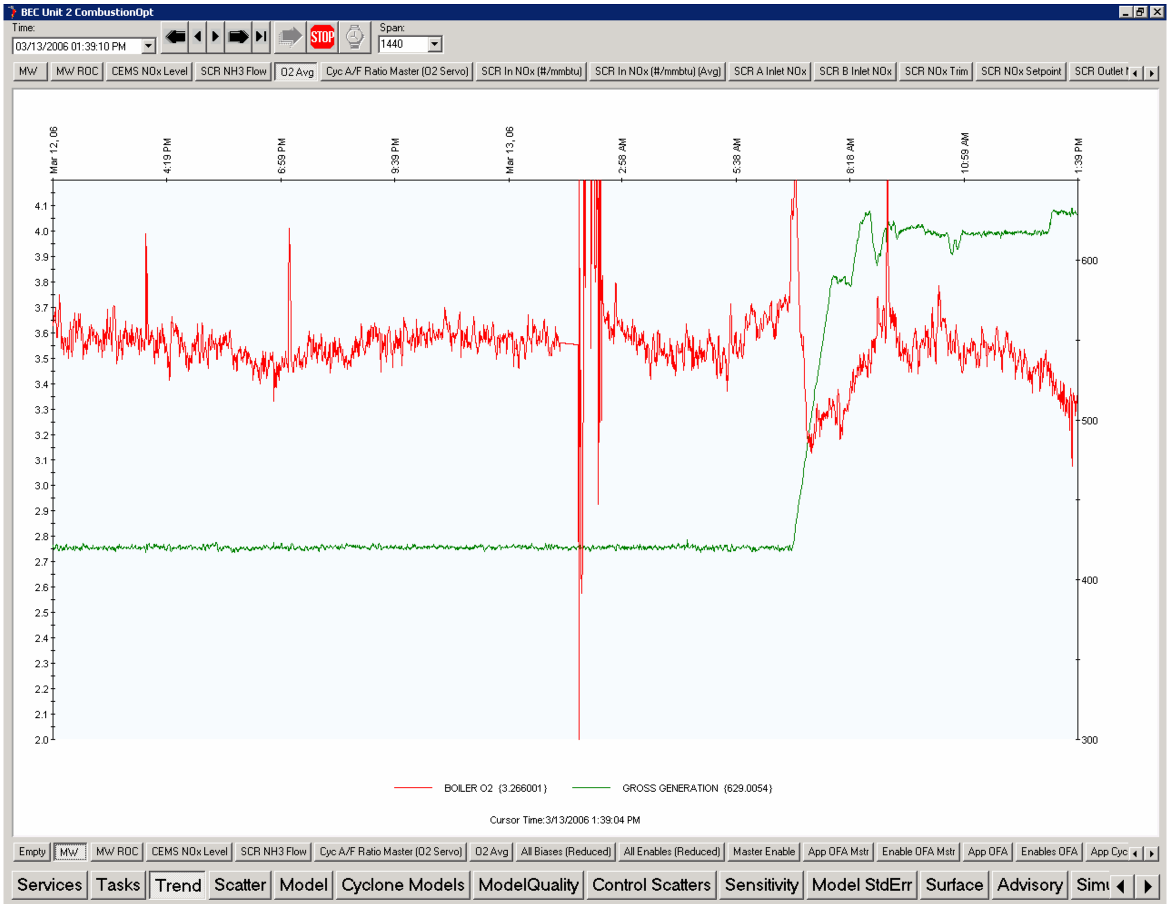

Figure 15 Load vs. measured boiler excess O2 (Figure 1 of 3)

This plot shows MW (green line) and measured boiler excess O2 (red line). At lower loads O2 is higher by design, for water-wall cooling and airflow maintenance. The green line shows that the unit had been running at a reduced load until the morning of 3/13. At full load the signal should run at around 3.2, however cyclone combustion, and OFA, O2 Servo interaction some threaten to push it higher. When this happens, the resulting control state, over time, can starve the cyclones and lead to a breakdown in combustion quality. For this reason CombustionOpt has been instructed to try and keep the measured O2 near its setpoint of 3.2. The lever it is expected to grab to do this (though it has not been explicitly told to do so and has had to discover the relationship specifically in the data it studies nightly) is OFA Master Bias.

Figure 16 Measured boiler excess O2 with OFA Master Bias (Figure 2 of 3)

This plot shows the measured boiler excess O2 (red line) along with the OFA Master Bias (green line). The right thing to do, to bring O2 under control, is to back the OFA Master down. This guarantees that in general the cyclones are getting sufficient air.

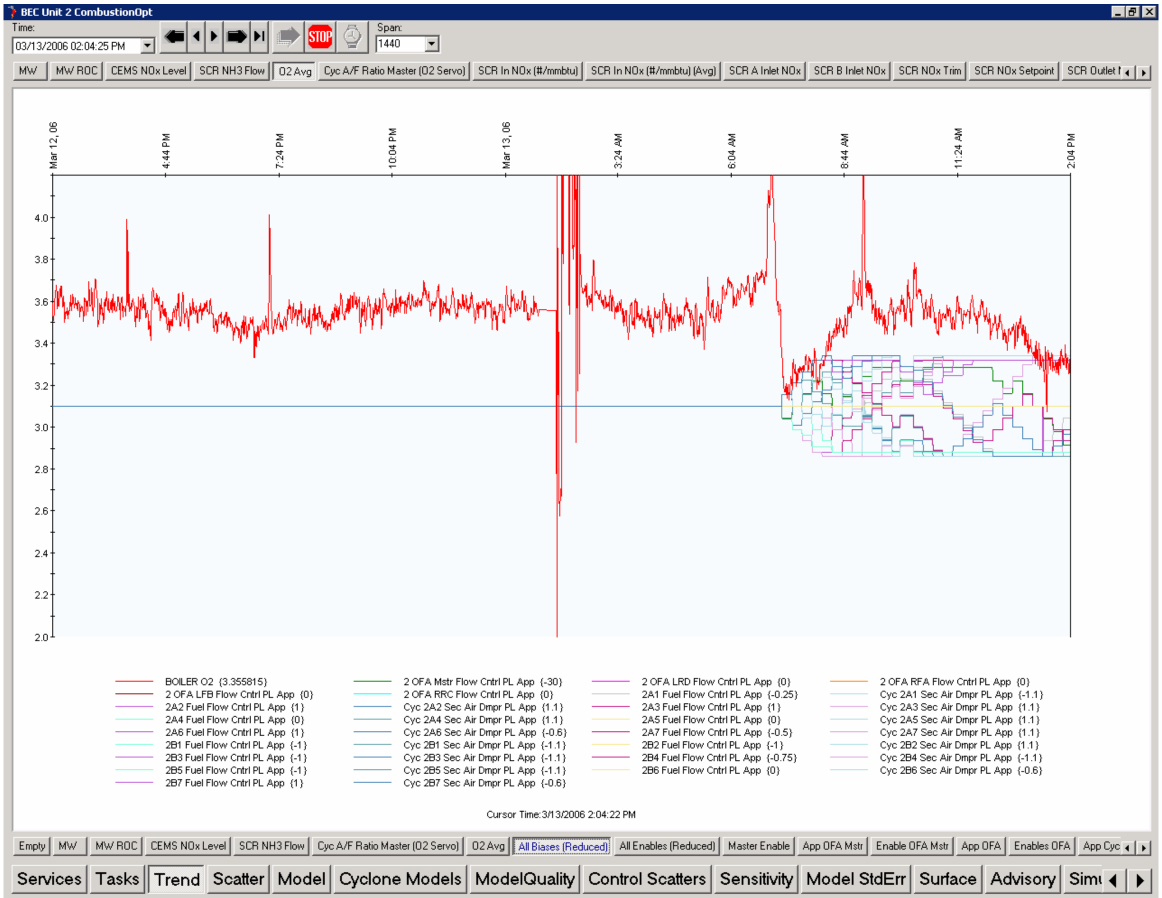

Figure 17 Load vs. biases (Figure 3 of 3)

Prior to the load pickup, CombustionOpt had been in 'neutral mode' waiting for appropriate conditions for optimization. As soon as those conditions were met, it began optimizing the cyclone secondary air biases, feeder biases and OFA Master Bias. As the high O2 objective dominated its efforts, it tried moving the cyclone biases, which are relatively small levers on both O2 and NH3 flown. When these made a dent but did not fully bring O2 under control, it began to step the OFA Master down.

In this case it was probably more idle than necessary, partly due to the relative simplicity of the expert rules that can be configured in V1.

Unit 2 has been imported into the new ProcessLink Platform (V2), and we are currently analyzing different ways of making provisions for more intelligent expert behavior.

3.2 SCR-Opt Results

3.2.1 Deployment

3.2.1.1 Goals for the Past Quarter

- Continue deploying new models and constraints to manage NH3 flow
- Upgrade to the most recent release of ProcessLink and the SCR-Optimizer

3.2.1.2 Accomplishments

ProcessLink migration and ongoing tuning

Work continued during the reporting period with tuning of the models of NH3 flow.

Both release V1 and V2 of our ProcessLink platform and SCR-Opt Optimizer is now running in closed loop under a new configuration on both Unit 1 and 2; we have been running both platforms in parallel for purposes of testing and validation during the reporting period.

3.2.1.3 Data Analysis

3.2.1.4 Goals for the Past Quarter

- Ongoing analysis of data

3.2.1.5 Accomplishments

Ongoing Analysis

The optimization objectives have been changed to focus on the NH3 flow (in addition to the O2 controller and the measured O2 value Optimization objectives reported in Section 3.1.2 above) during the reporting period. This is in response to discussions held with Baldwin (Sam Krueger and Operations management staff) week of Dec 15, 2005. The tuning is on-going but initial results are interesting; please see the combined studies with CombustionOpt presented in Chapter 3.1.2.2., *Figure 2* - *Figure 14*, and especially *Figure 2*, *Figure 3*, *Figure 8*, *Figure 9*, *Figure 11*, and *Figure 14*.

3.3 SootOpt Results

3.3.1 Deployment

3.3.1.1 Goals for the Past Quarter

- Ongoing closed loop operation at BEC Unit 3, OMU Unit 1 and 2
- Continue the efforts around ProcessLink V2 migration
- Continue deploying new models and constraints to manage sootblowing activities as well as fine tune models
- Documentation

3.3.1.2 Accomplishments

Closed Loop Operation

At Baldwin Unit 3, SootOpt has continued to run in closed loop throughout the reporting period, using the newest release of the software. We have focused the optimization efforts on individual flux zones.

The SootOpt deployment at OMU Unit 1 and 2, which features a rules-based approach as a starting point, has continued to run in closed loop intermittently when unit conditions are conducive to closed-loop operation (unplanned outages, plant operational (mechanical) limitations and emissions testing and measurement issues came in the way of closed-loop testing activities). OMU Unit 2 began its scheduled outage towards the end of this reporting period. The outage is expected to last till late April.

ProcessLink V2 migration

The migration to the new platform (V2) has been ongoing for all three units during the period and work on running SootOpt in the new platform for extended periods has been ongoing.

Work on neural modeling and flushing out the views for the V2 version continues. Work on calculations to support reporting of sootblowing activities is in progress.

Ongoing tuning

The configuration of various calculations to determine soot blower operation frequency (TimeSinceLastOperation) was accomplished at OMU Unit 1 and performed. The results of these calculations were utilized in the configuration of the heuristics engine for Unit 1; the heuristics and resulting actions were observed and verified against normal plant operating data to ascertain reasonable behavior. Updated operational constraints and heuristic engine were verified to function appropriately first in open-loop fashion and then in closed-loop when unit conditions were conducive to SootOpt control.

Based on observations made during closed-loop mode, plant operations personnel at OMU identified a couple of additional constraints and NeuCo worked with incorporating these additional constraints in the SootOpt application during the reporting period. These constraints were aimed at better managing soot blowing air supply between the two units, minimizing opacity excursions from historical levels to help with plant's regulatory requirements and ensuring sufficient blowing under a diverse set of operating conditions as well as plant operational issues.

Many different models were trained using soot blowing frequency as well as boiler parameters and are being analyzed. Additionally OMU plant personnel have identified minimization of Opacity excursions and better management of soot blowing air supply as constraints for both Units and NeuCo is working to incorporate them within the SootOpt application.

Documentation

Documentation of operational constraints and control considerations was undertaken during this reporting period. Copies of documents were provided to site operations personnel to enhance their understanding of SootOpt and invite feedback.

3.3.2 Data Analysis

3.3.2.1 Goals for the Past Quarter

- Analyze data trends to verify applicability and appropriateness of various signal processing functions and heuristics for SootOpt
- Closely review performance of SootOpt in closed loop

3.3.2.2 Accomplishments

Ongoing Analysis

SootOpt continues to run in closed loop at Baldwin and OMU and data are continuously collected and analyzed.

Based on requests from users, we developed and implemented an operator pause signal; this will allow the effect of SootOpt on the operator's objectives to be observed. If the operators are required to pause less often, that means that SootOpt is working for them to automatically manage the RH temps and sprays they are usually reacting to.

Analysis of process data has provided an increased understanding of relationships between soot cleaning control actions, timing relationships, and their effects on various boiler parameters. Accordingly the heuristics engine is being tuned to account for such relationships, as well as appropriately adjust idle times between steps in a sequence.

Further analysis and integration of cleanliness factors that are provided by PerformanceOpt is underway. These signals in conjunction with the expert algorithm will serve to more intelligently direct operation of the soot cleaning devices considering a complex set of global objectives and operational constraints.

Preliminary analysis of model results points to reasonable model predictions.

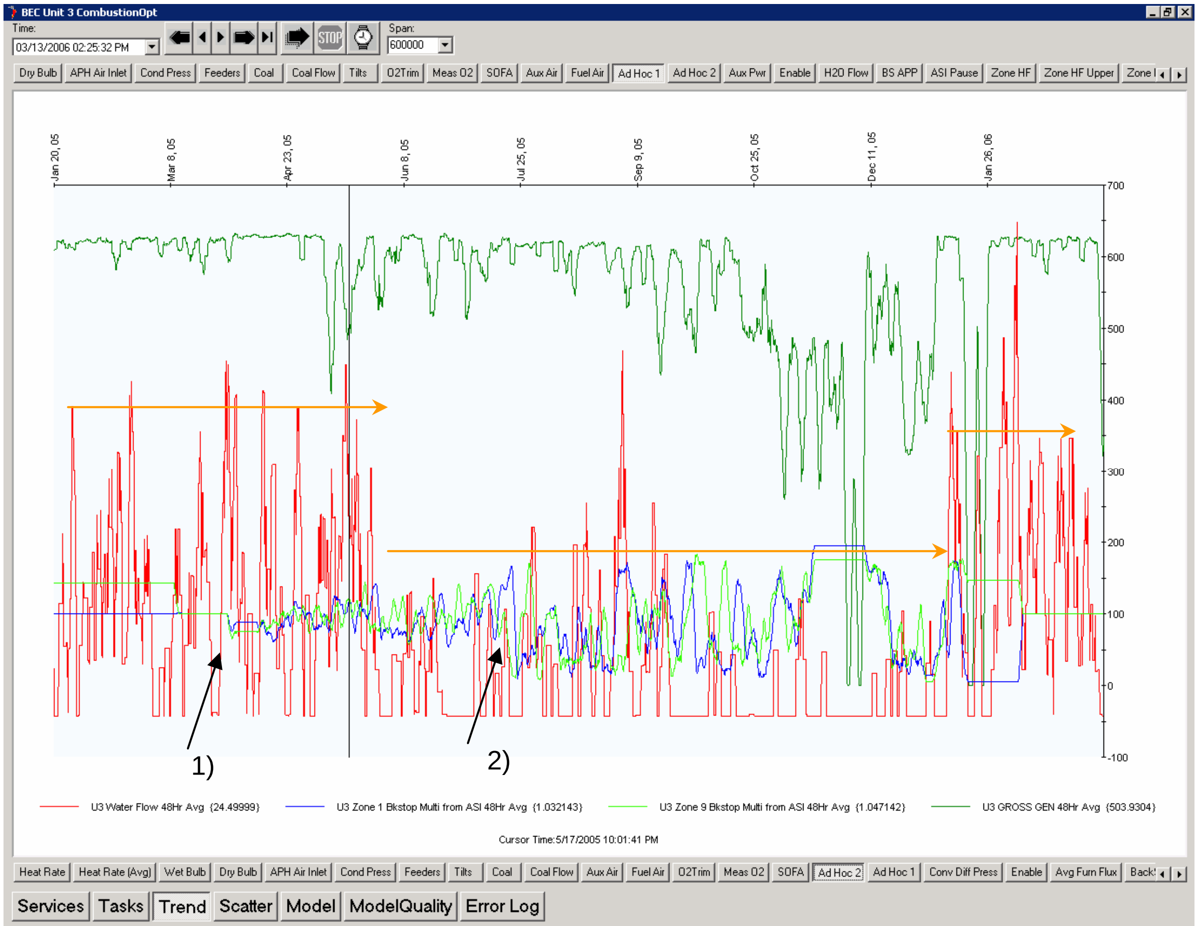

Figure 18 Case Study Baldwin Unit 3

This trend shows the water cannon flow (red line) along with the flux target biases (light green and dark blue lines), and MW (dark green line) from January 2005 thru March 2006.

The orange arrows highlight differences in cannon water usage (and so cleaning frequency). Black arrow 1) shows where SootOpt was installed and began biasing flux targets. Black arrow 2) shows where the bias limits available to SootOpt were widened.

Reduced cleaning frequency indicated by reduced water flow would be consistent with the tendency of SootOpt to bias the flux targets down more than up (although the bias activity does range). In this plot however, the 'de-slagging' effects of brief periods of lower load, more common to the middle region, cannot be ruled out as the primary cause for reduced need for cleaning.

3.4 PerformanceOpt results

3.4.1 Deployment

3.4.1.1 Goals for the Past Quarter

- Configure the full initial set of trigger variables
- Deploy PerformanceOpt on-line on Unit 2
- Refinement of models and user interface

3.4.1.2 Accomplishments

The Unit 1 model continues to run and we have been testing the convergence routines to improve the real-time success rate in order to get better application performance. We have also been working on the software to improve the consistency of the results and to minimize the time required to update data on the user screens. We have also started to add new trigger variables monitored by PerformanceOpt to evaluate the cost impact on current operations.

Trigger Variables

We have added three new triggers to PerformanceOpt to identify suboptimal unit performance: Reheat Steam Temperature, Main Steam to the Boiler Feed Pump Turbines, and Reheat Spray Flow. The main steam and reheat spray flows are primarily indications of leaking valves, but they do have an impact on heat rate if they are not needed. Low reheat temperature can be addressed by modifying the sootblowing sequences, providing a better balance between the reheat and superheat zones; recent results can be found in *Figure 20 - Figure 22* below. We will continue to add additional triggers, identified in discussions with plant engineering personnel, over the next reporting period.

Ongoing Model Improvement

Now that PerformanceOpt is in routine operation, we have asked Tim Tidwell at Baldwin to provide NeuCo with feedback on the application. His first review included recommendations for additional trigger variables, such as condenser backpressure and flue gas O2 that will be added to our current list of variables that PerformanceOpt monitors.

Deployment of PerformanceOpt on Unit 2

During the reporting period we have completed the building of the flowsheets and display screens setup as well as QA to make sure all fields were displaying correctly. The False Constants check has been completed and a final check from an independent reviewer at B&V was performed. The model was deployed in test mode when the boiler is running normally with all sensors working and all equipments working as designed, and was working fine..

We were slowed down by some equipment or sensor malfunctions at the unit which caused the model to fail. The problems included (1) SH Attemperator flow sensor not working correctly caused a sudden drop in the feed water flow to the roof tubes (2) condensate pump with a sticking re-circulation valve causing the operators to reroute the water flow and bypass equipments again

causing both a mass and energy imbalance in the simulation which cannot be solved. Baldwin has to resolve these issues.
The model was implemented towards end of Q1 and has been running on line for the last few weeks. The homepages that have been configured show the results of the plant. The model was reviewed again of an independent source to ensure quality and accuracy.

We will then continue to enhance to the model by adding the achievable specifications and trigger variables throughout the next reporting period.

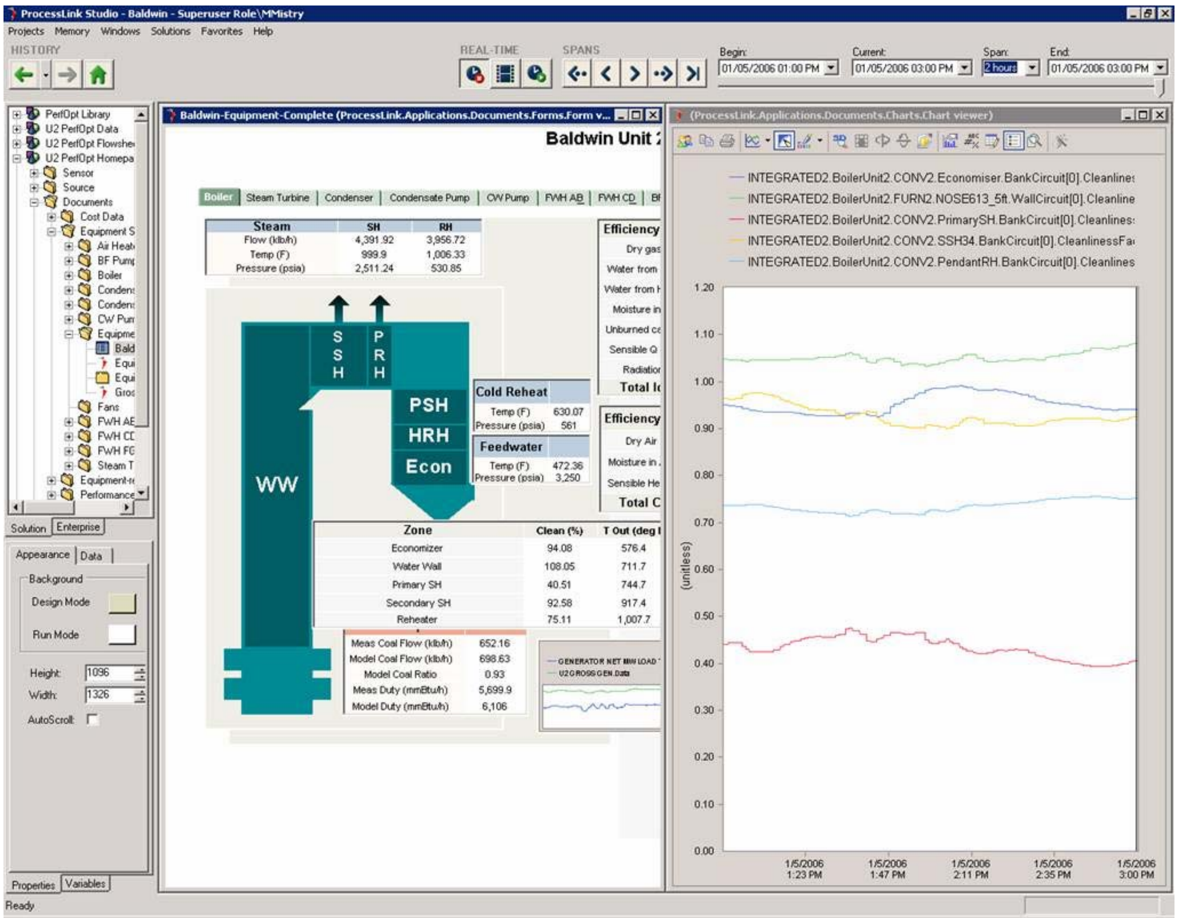

Figure 19 PerformanceOpt Unit 2

3.4.2 Data Analysis

3.4.2.1 Goals for the Past Quarter

- Ongoing data analysis

3.4.2.2 Accomplishments

Ongoing Model Improvement

The model improvements have been ongoing during the period; we have been fine-tuning the model convergence algorithms - while the Real-time model has been reliably converging under all plant conditions, the Achievable Scenario simulation (used to calculate individual and overall expected values) had to be improved. Although these non-converged solutions involve only one or two variables, we will continue to analyze and fine-tune the application.

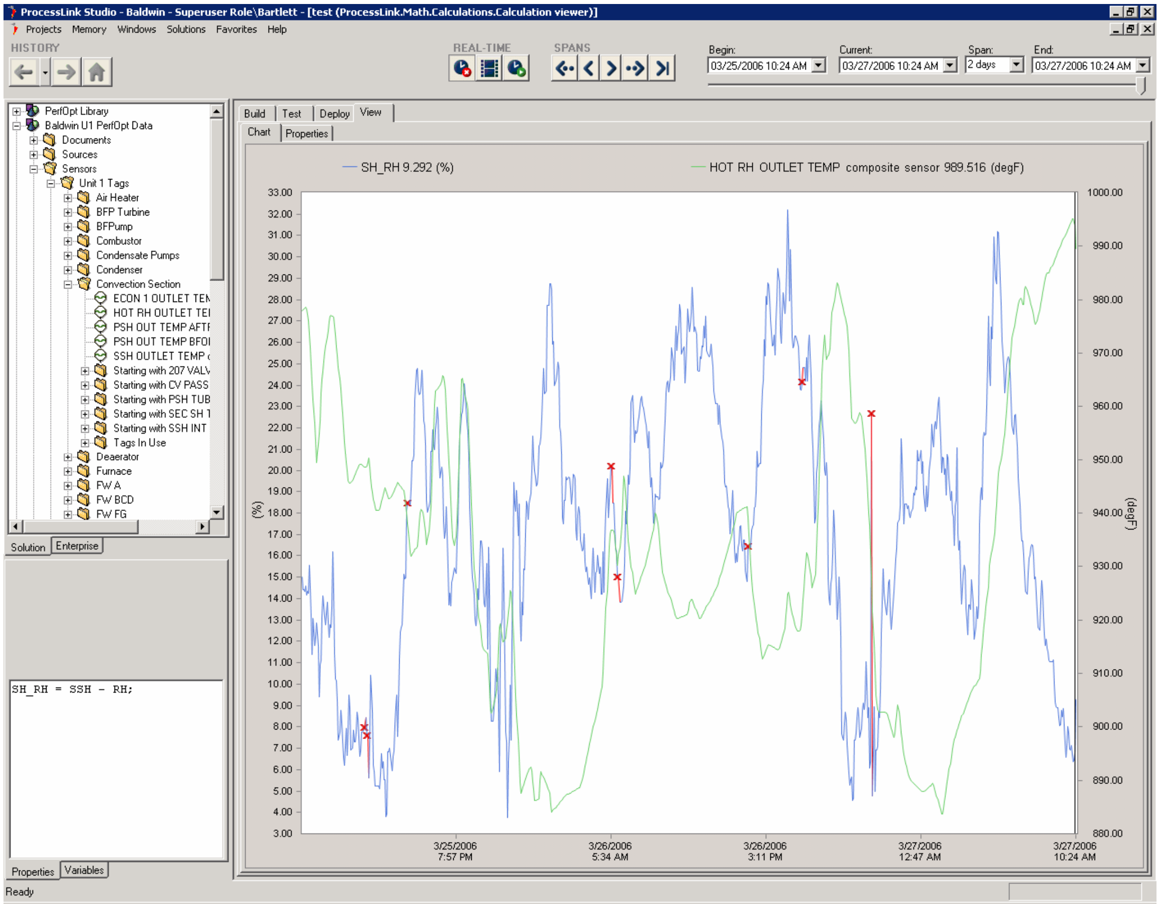

Figure 20 Effects of Cleanliness Factors on RH Temperature

Figure 20 shows the effects of Cleanliness Factors on RH Temperature. The blue line represents the difference between the cleanliness factors for the Secondary Superheat Zone and the Reheat Zone. The green line is the measured reheat temperature. These are inversely proportional; when the relative cleanliness of the secondary superheat zone is high (and the reheat zone is low), reheat temperature is low. Shifting sootblowing capacity from the secondary superheat to the reheat zone will make more heat available to the reheat coils, increasing reheat temperatures.

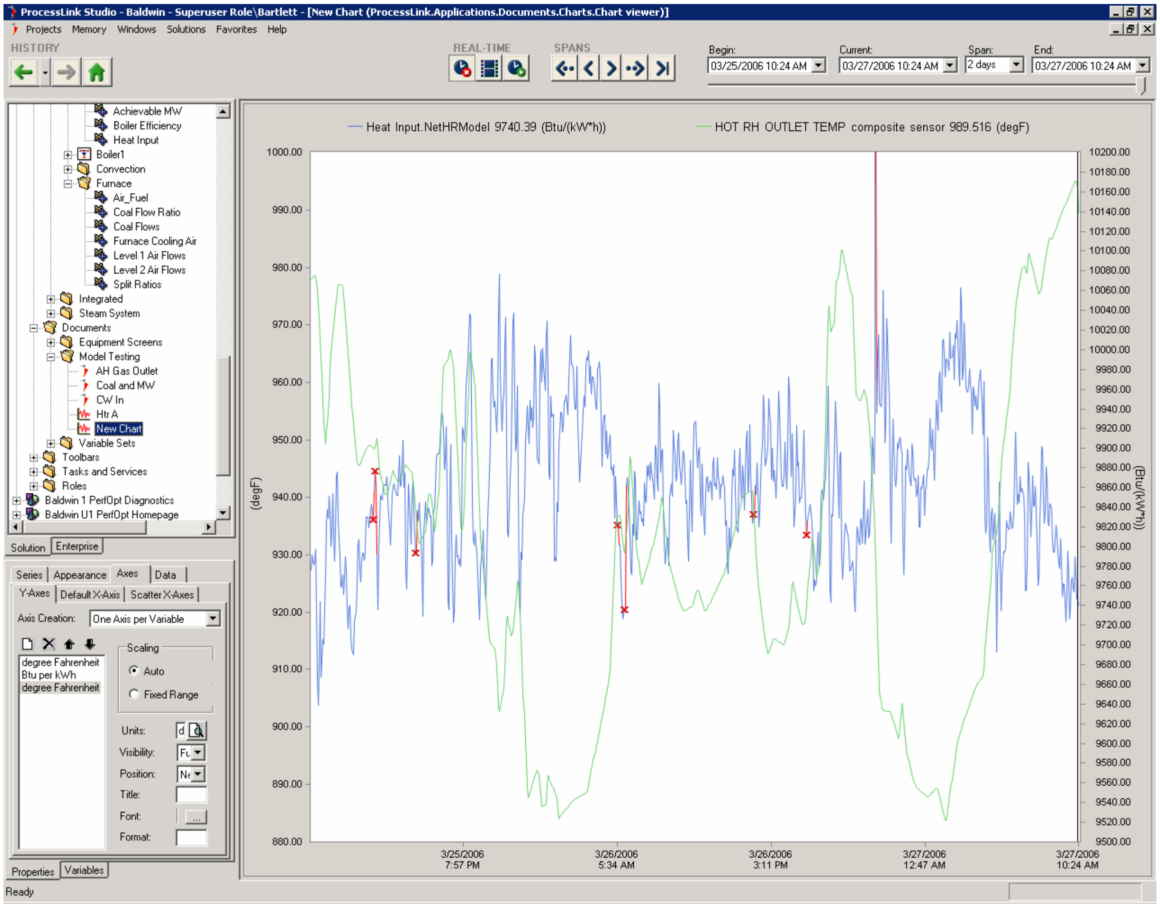

Figure 21 Effects of Reheat Temperature on Net Unit Heat Rate

This plot shows the impact of Reheat Temperature on Net Unit Heat Rate. Reheat temperature has a clear impact on heat rate. Heat rate is high when reheat temperature is low. Fuel costs can therefore be minimized by maximizing reheat temperature.

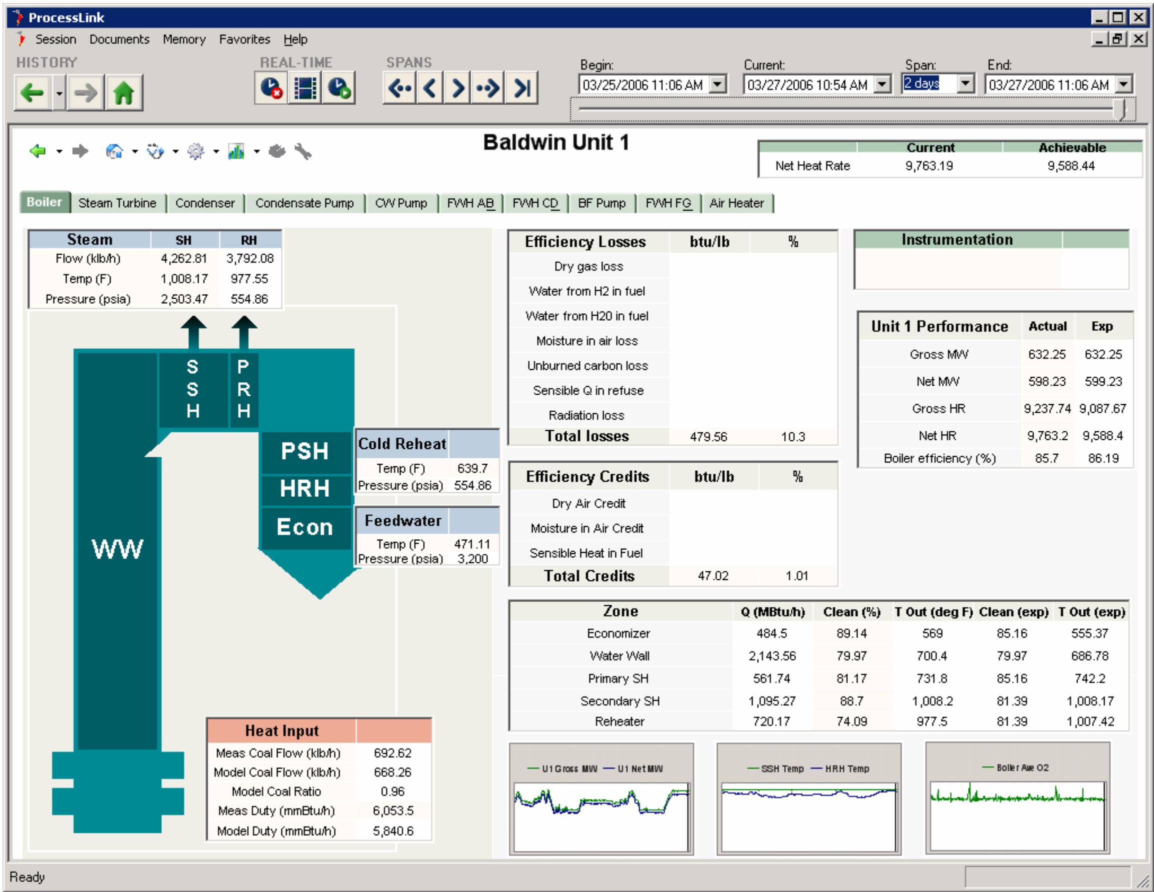

Figure 22 Boiler Cleanliness Recommendations

This figure shows the Boiler Cleanliness Recommendations. Increasing the reheat zone cleanliness does not occur in isolation, as sootblowing capacity is limited. Improved reheat temperature can be achieved by increasing reheater zone cleanliness from 74 to 81% while decreasing the cleanliness of the secondary superheater zone from 88 to 81%. This implies a shift in the sootblowing schedule, not an increase in overall sootblowing activity.

3.5 MaintenanceOpt Results

3.5.1 Deployment

3.5.1.1 Goals for the Past Quarter

- Continue the configuration of MaintenanceOpt
- Deploy real-time diagnosis

3.5.1.2 Accomplishments

Configuration

One new trigger variable and cost impact has been added to the MaintenanceOpt displays - the main steam to the boiler feed pump turbines

Diagnostic Service

The real-time service that detects problems for diagnosis through MaintenanceOpt has continued to run during the reporting period, providing input to the PerformanceOpt and MaintenanceOpt Home Pages.

3.5.2 Data Analysis

- Ongoing data analysis

3.5.2.1 Accomplishments

Ongoing Analysis

The data obtained from real-time operation of MaintenanceOpt has been closely monitored during the reporting period, giving us a knowledge base to further improve the Optimizer and its functionality.

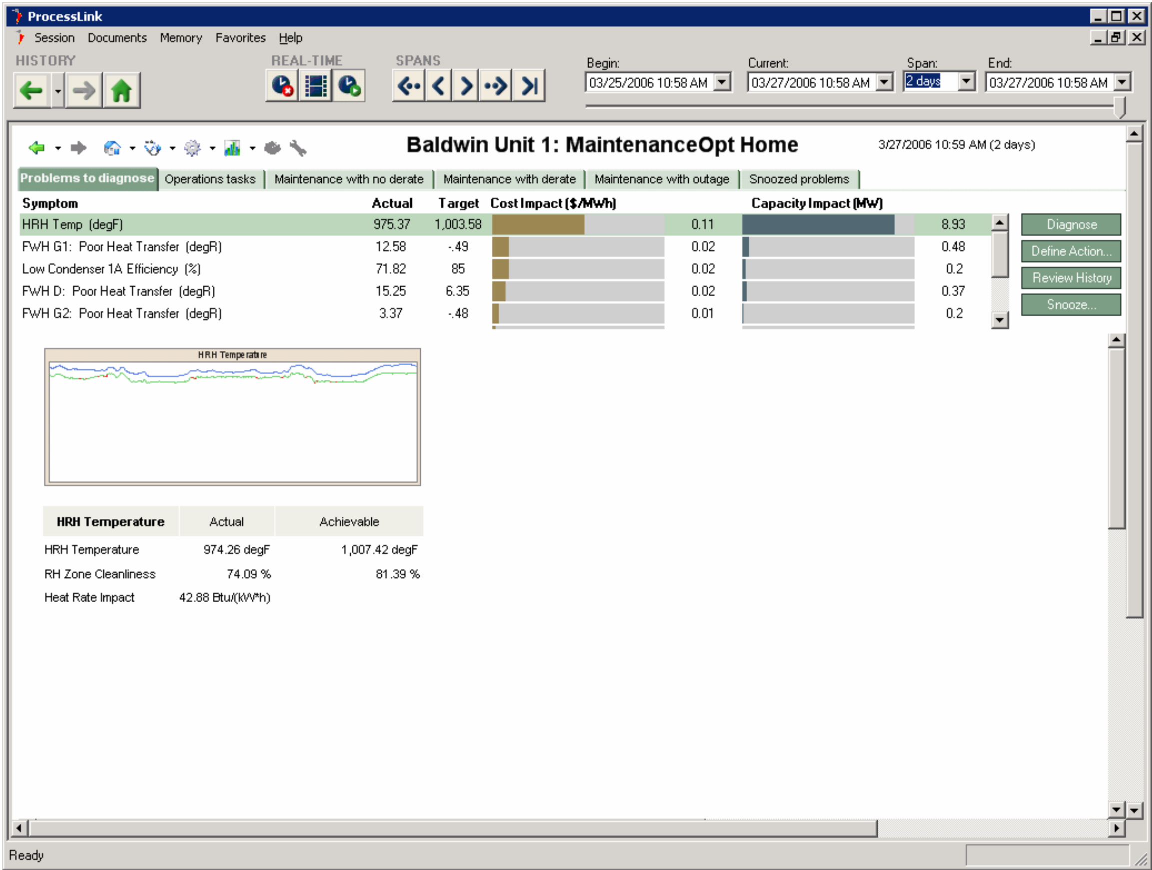

Figure 23 MaintenanceOpt Home Page: Current PerformanceOpt Recommendations

This screen shows Current PerformanceOpt Recommendations on the MaintenanceOpt Home Page. Reheat temperature is over 30 degrees F below its achievable value, which could be met by raising the RH zone cleanliness from 74 to 81%. The heat rate impact is 42 Btu/kWh, or 11 cents per MWh.

4 Conclusion

CombustionOpt

The Optimizers continue to run in closed-loop on Units 1, and 2; installation of CombustionOpt on Unit 3 is underway and the Optimizer is on-line in DOE. Both release V1 and V2 of the ProcessLink platform and the CombustionOpt Optimizer have been running in parallel for testing and validation purposes on Units 1 and 2. Substantial effort has been put into the QA work of the new release of CombustionOpt, as well as the user interface and supporting functionality. Data analysis and refining of the models based upon the results are on-going.

SCR-Opt

The Optimizers continue to run in closed-loop on Units 1, and 2; both release V1 and V2 of the ProcessLink platform and the SCR-Opt Optimizer have been running in parallel for testing and validation purposes. New configurations, focusing on NH3 flow, have been deployed on both versions. Substantial effort has been put into the QA work of the new release of SCR-Opt, as well as the user interface and supporting functionality. Data analysis and refining of the models based upon the results are on-going.

SootOpt

The Optimizer has been running in closed loop throughout the period on Unit 3 and at OMU Units 1 and 2. Discussions with the soot cleaning vendors has been ongoing throughout the period, in order to further deepen the knowledge about their systems and to delineate the effect that SootOpt is having on their systems. Data analysis and refining of the models based upon the achieved results are on-going; we have been focusing on gaining more knowledge around the soot cleaning control actions, their timing relation ships and their impact on various boiler parameters.

PerformanceOpt

NeuCo has continued to work with Baldwin and Black and Veatch to add additional trigger variables to the models. The deployment of PerformanceOpt on BEC Unit 2 is completed and the models have been running on-line throughout the period. Data analysis and refining of the models based upon the results are on-going.

MaintenanceOpt

The integration of PerformanceOpt and MaintenanceOpt has been progressing; we can now show PerformanceOpt recommendations on the MaintenanceOpt Home Page. By combining the trigger variables with corresponding cost impacts, a more detailed clarification could be achieved to clarify where the largest opportunities for improvements/costs savings are. Next steps involve prioritizing the set of knowledgebase triggers and diagnostic rules to deploy for maximizing coverage of the controllable losses that the plant engineering personnel currently are monitoring. Data analysis and refining of the models based upon the results are on-going.

5 References (Not Applicable)

6 List of Acronyms and Abbreviations

API	Application Programming Interface
ASI	Applied Synergistics Inc.
BEC	Baldwin Energy Complex
BTU	British Thermal Unit
B&V	Black & Veatch
CCPI	Clean Coal Power Initiative
CMMS	Condition Monitoring Maintenance System
CO	Carbon Monoxide
CO2	Carbon Dioxide
DCS	Distributed Control System
DMG	Dynegy Midwest Generation
DOE	Department of Energy
EEGT	Economizer Exit Gas Temperature
EPRI	Electric Power Research Institute
ESP	Electro Static Precipitator
FCM	ASI's Furnace Cleanliness Module
FD	Forced Draft
FF	Functional Failure
FGD	Flue Gas Draft
FT^3	Cubic Feet
GUI	Graphical User Interface
HMI	Human Machine Interface
HR	Heat Rate
H2O	Water
ID	Induced Draft
ISB	Intelligent Sootblowing
LAN	Local Area Network
LOI	Loss on Ignition
Mol Wt	Molecular Weight
mmBTU	Millions of BTUs

mm	Million
MW	Megawatt
mWh	Megawatt hour
M/year	Million per year
N2	Nitrogen
NH3	Ammonia
NOx	Nitrogen Oxides
O2	Oxygen
OEM	Original Equipment Manufacturer
OFA	Over Fire Air
OMU	Owensboro Municipal Utilities
OPC	OLE for Process Control
OPM	On-line Performance Monitoring
PAS	Primary Air Shrouds
PC	Personal Computer
PF	Potential Failure
PE	Processing Elements
PI	Plant Information
PL	ProcessLink
PLC	Programmable Logic Controller
ppm	parts-per-million
PRB	Powder River Basin
PTC	Power Test Code
RH	Re heater
S	Sulfur
SAS	Secondary Air Shrouds
SBCS	Soot Blowing Control System
SCE	ASI's Sootblower Control Expert
SCR	Selective Catalytic Reduction
SH	Super Heater
SNCR	Selective Non-Catalytic Reduction
SO2	Sulfur Dioxide
SO3	Sulfur Trioxide

TCV	Temperature of Critical Viscosity
TC	Thermocouple
VPN	Virtual Private Network